TECHNICAL TEACHING IN THEORY AND PRACTICE

FOR TEACHERS IN TECHNICAL SCHOOLS AND COLLEGES

By

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IN THEORY AND PRACTICE

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PREFACE

Of the large number of graduates in Pure and Applied Science who enter the teaching profession annually, the majority pass into Elementary or Secondary Schools and a smaller proportion become full-time teachers in Technical Colleges. Most of the first group have received more or less systematic instruction in the Theory and Practice of Education, and an increasing proportion of the last group, who have graduated in Pure Science, have acquired a Teacher's Diploma by a year of post-graduate study. But in no case does the training deal with the specific problems and subjects of Technical Education.

Just as the main volume of Technical Education in the country is provided in part-time classes, so also the main body of the work is in the hands of part-time teachers. Many of these are engaged in Elementary or Secondary Schools and many are engaged in some industry or some profession other than teaching. Among these, as well as among the full-time members of the staffs, are many excellent teachers. They have knowledge, personality, and a natural aptitude for presenting a subject in a clear, orderly manner. And with each year of experience they improve. But unless they are aware of the reasons for the methods they

employ they cannot transmit their skill to subordinate or younger colleagues.

Until recently there has been no machinery either for the provision of specific training in principles, or for securing that the accumulated experience of one generation shall be available for the next. But during the last dozen years the Board of Education and certain Local Education Authorities have provided a number of Short Courses in which the specific problems of Technical Education have been studied. In a few cases these have consisted of, or have included, the Principles of Teaching ; but for the most part attention has been directed to improving the students' grasp of the subject, and the training in teaching has been based upon example rather than upon principle. In spite of this and other limitations, the courses have been of immense benefit to teachers, and through them to the students and to the industries in which they are engaged.

For thirty-nine out of the last forty-one years the author has lived, in one capacity or another, in the Technical Schools and Colleges of this country. During that time he has had unusual opportunities of observing the discouragement and economic loss which results from each generation of teachers having to carry on their work without special training or the benefit of transmitted experience ; and he has responded, not unwillingly, to the suggestion that he should publish his gatherings of the years for the benefit of those who are just entering, or have just entered,

the profession, whether this be in a full-time or a part-time capacity. The book is the result not merely of observation and teaching experience, but of hundreds of lectures, formal and informal discussions, and talks to many types of teachers, in a wide variety of subjects, over a long period of time.

The psychological basis has been reduced to very small proportions. The students in part-time classes are not children, and they attend, for the most part, because they have a desire to learn. Many of the subtleties of the child-mind have disappeared, and there is less difference in maturity between the minds of the teacher and students. Moreover, the great variety of general education, occupational experience, and subjects taught in Technical Schools and Colleges, call for a corresponding variety of method. It seemed desirable, therefore, to provide a simple framework of Theory and to indicate on the one hand its universal application and, on the other hand, the modifications and variations necessitated by the age and type of student, and the nature of the subject.

Parts of Chapter IV, and more especially Chapters V and VI, are didactic. They " lay down the law ". But for this attitude—the result of temperament and experience—the author cares neither to offer an excuse nor to present an apology. No syllabus or method is treated so fully as to constitute a cast-iron model. There is room for elasticity. There is no Bright Heaven to which the author can secure the

admission of a teacher who adopts his recommendations ; no Dismal Hell to which he can condemn him if he rejects them. But if the book enables teachers to understand something of the why and wherefore of their methods, and if it prompts them to take a greater and more intelligent interest in their work, it will have served its purpose.

C. H. C.

April, 1935.

TECHNICAL TEACHING IN THEORY AND PRACTICE

CHAPTER I

INTRODUCTORY

Teaching is a specialized occupation. Some men are born teachers. They have orderly minds, an adequate vocabulary, a command of clear, precise expression, and a natural aptitude for seeing into the minds of those whom it is their business to instruct or train. Others require training if they are to accomplish their purpose with reasonable efficiency.

Even the born teachers are better for it. There is almost sure to be some aspect of their rôle for which they do not make provision. And a man is more sure of, and has more confidence in, his methods if he understands the principles which lie behind them. Moreover, if he ultimately occupies a position of responsibility in which he may or should exercise supervision over younger and less experienced colleagues, he will find it difficult to render that aid which they need, and which he desires to give them.

No method of teaching is ever satisfactory unless

the teacher himself is clear as to the purpose of the instruction. He should, therefore, ask himself at the very beginning of his career, " What is my purpose ? " " What is my aim ? " " What do I seek to achieve in this work I have undertaken ? " " Primarily," he may say, " it is to ensure that my students know certain things or can do certain things at the end of the year." So far, he would be correct. He would have stated the immediate object of his efforts. But it is only half the truth. No educational work worth the name begins and ends with a year's activity. The technical student may have already learnt a good deal when he enters the class, but he has not learnt everything there is to be known after a year of study. If the teacher's work is to be effective, it should have regard not only to what has been done, but to what may be done. He should seek to give his students not only an abiding interest in the subject, but he should endeavour so to train them in habits of study that they will go on learning after they have left him. *The main function of the teacher is to train students to learn for themselves.*

This does not mean that the students are necessarily to become scholars, devoting their lives to learning, but that they should have acquired such habits that if they want to know anything or do anything subsequently they will know how to set about it. They need not be conscious of the fact that they are being trained in this way. We do not *think* about what we do habitually :—

The centipede was happy quite
  Until the toad—in fun—
Said, " Pray which leg comes after which
  When you begin to run ? "
This wrought her mind to such a pitch,
She lay distracted in a ditch,
  Considering " How to run ? "

Nor does it mean that the subject is of no importance. The student is still expected to *know* certain things and to be able to *do* certain things at the end of his course, and the *method* of teaching must vary with the subject. For the moment the subjects of instruction may be divided broadly into two groups—those in which the student acquires *knowledge* and those in which he acquires *skill*. The two groups are not mutually exclusive. It is impossible to acquire knowledge without obtaining skill in practical arts, such as writing, speech, drawing, or manual dexterity in the laboratory or workshop. And it is equally impossible to acquire skill in laboratory work or craftsmanship without acquiring knowledge of tools, materials, and processes, including the machinery or other appliances which these processes may involve. Nevertheless, in one group the acquisition of knowledge must be the main purpose and in the other group the attainment of skill.

It is obvious that in order to decide how to deal with a subject of instruction it is necessary to have some idea of the nature of knowledge and skill. We will consider knowledge first.

All knowledge is based on experience. From the time a child is born it begins to have experiences.

At first the cause or source of these experiences is not recognized. But the frequent association of a certain person, or certain conditions, with an event connects the two in the mind. As John Tyndall so aptly and vividly expressed it :—

"The first experiment a child makes is a physical one : the suction pump is but an imitation of the first act of every new-born infant. Nor do I think it calculated to lessen that infant's reverence or to make him a worse citizen, when his riper experience shows him that the atmosphere was his helper in extracting the first draught from his mother's breast. The child grows, but is still an experimenter : he grasps at the moon, and his failure teaches him to respect distance. At length his little fingers acquire sufficient mechanical tact to lay hold of a spoon. He thrusts the instrument into his mouth, hurts his gums, and thus learns the impenetrability of matter. He lets the spoon fall, and jumps with delight to hear it rattle against the table. The experiment made by accident is repeated with intention, and thus the young student receives his first lessons upon sound and gravitation. There are pains and penalties, however, in the path of the inquirer : he is sure to go wrong, and Nature is just as sure to inform him of the fact. He falls downstairs, burns his fingers, cuts his hand, scalds his tongue, and in this way learns the conditions of his physical well-being. This is Nature's way of proceeding, and it is wonderful what progress her pupil makes. . . ." [1]

[1] *Fragments of Science*, vol. i. Sixth Edition, p. 335.

While continually enlarging his experiences of the physical world, the child adds experiences of men and women, of family life and social customs until, when he comes to school, he already possesses an enormous store of knowledge obtained at first hand.

But that is not all. From the time he began to understand and to use speech he has heard of many things of which he has no direct experience. He believes in these things—people, objects, places, events, phenomena, because they are in harmony with, or at least not in conflict with, what he has learnt through his senses of sight, hearing, smell, taste, and touch—the five gateways of knowledge. As he grows and learns to read this mass of belief overtakes and far exceeds the nucleus, or core, of experience. And in time the beliefs become almost as real to him as that which he has obtained at first hand. In fact many people lose the distinction altogether. For our purpose, however, the essential fact is that knowledge is dual in character, and that the foundation of it is direct contact with reality.

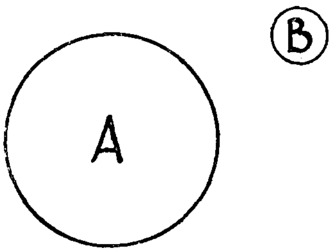

FIG. 1.

On this fact are based several old, and well-worn, but still useful maxims. One of these is to the effect that *teaching should proceed from the known to the unknown, or from the more to the less familiar.* This can

be illustrated diagrammatically. Suppose that *A* in Fig. 1 represents what a student knows, and *B* represents what he has to learn. Then the teacher should not talk entirely about *B*. In many cases he need not mention *B* for a time. He should just endeavour to emphasize the ideas in *A* which have a natural association with *B* and then he should expand *A* until it absorbs *B* as in Fig. 2. It follows that *B* should not be too remote from *A*. If it is remote then it should be approached by stages. If in the expansion of *A* there are groups of ideas *X* and *Y* which must be acquired before *B* can be understood, then *X* and *Y* should be dealt with first. We shall give a reason for this later.

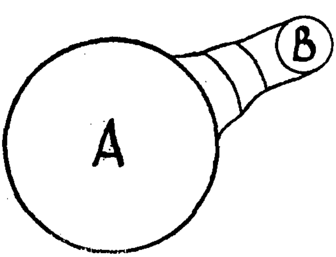

FIG. 2.

The use of the diagrams can be extended. If the students are of school age *A* will consist of two portions—A_1 the common everyday experiences of children of this particular age and special group, and A_2 the work done previously in school. The diagram will now be as in Fig. 3, and the teacher will exercise his judgment as to

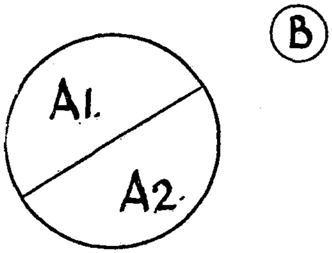

FIG. 3.

whether to start in A_1 or A_2. Very frequently both stores of knowledge have to be utilized.

The older the student the larger and the more varied will be his mind-content. When he leaves school and enters upon the serious task of earning a living he will become familiar with materials and processes, facts and phenomena, and probably also a social organization, which have hitherto been outside his experience. With this experience will be associated many beliefs which may arise from what he has heard, or read, or from his own interpretation of what is going on around him. The diagram may, therefore, be extended as in Fig. 4, in which A_1 and A_2 have the same significance as in Fig. 3, and A_3 represents the occupational experience. It is obvious that the older a man becomes the more completely is his occupational experience likely to dominate his mind—at any rate, so far as technical instruction is concerned.

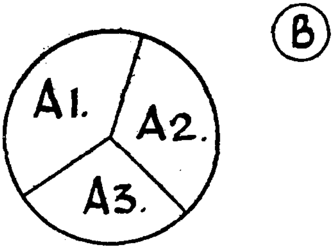

FIG. 4.

These two maxims impose upon the teacher the obligation to familiarize himself, as early in the session as possible, with the previous education, general and special, and with the occupations of his students. Until he has that information he cannot teach from the known to the unknown or from the more to the less familiar. Moreover, he is liable, in a subject like

mathematics, for example, to discourage students by making them do work in which they are already tolerably proficient. The simplest and quickest way of obtaining the information is to write down on the blackboard a few questions as to education and occupation, and to ask the students to supply the information. The sheets can be examined at leisure and retained for reference.

There is another old maxim which advises the teacher to proceed from *the particular to the general.* This means that facts should be considered before general principles or formulae are introduced. It represents the method by which, in general, human beings have progressed in mental power and understanding. General ideas do not present themselves to a mind devoid of individual examples. Rather are they reached as a result of the consideration of large numbers of individual cases. Only then can the existence of a general law or principle be recognized. The alternative process, the statement of a general law followed by its proof, is peculiar to mathematics, and it is not a procedure for which the minds of most boys and girls and men and women are adapted.

A fourth maxim recommends that the teaching should proceed from *the simple to the complex.* This means that simple ideas should be dealt with first, and that these should then be enlarged or fused to form more comprehensive groups. Thus an outline of a topic should precede a more detailed consideration. Or an historical approach to a subject may be desirable because in the early stages the processes were simple,

and later developments have been rather of the nature of elaboration of the original than the application of new principles.

Now *skill* is a term used to denote dexterity in the practical arts—speaking, writing, drawing, laboratory work, workshop exercises, and the domestic crafts. The essential character of all practical arts is that they are based in the first instance on imitation and are improved by practice. Again it is rare for any boy or girl, man or woman, to attend a class who is entirely devoid of skill. Children, and men and women are always doing things, or trying to do things, and they base their efforts on what they have seen or read of the activities of other people.

There may have been, at some time in the history of mankind, a period in which men and women developed crafts entirely on their own initiative. But that is not so in the rich and varied world of to-day. An individual may modify, or elaborate, or use new materials, or apply a method in a different way, but there is some knowledge or experience behind their apparent innovation.

The most useful of the four maxims in regard to the practical arts is the last. It is obvious that more satisfactory progress will be made if the earlier exercises are those which are more easily executed. The " ease " of execution depends in some cases on the material, and in other cases on the tool. Not only will these simple exercises train the eye and muscular sense so that the more difficult operations may come within the capacity of the student, but the more satisfactory

results act as a stimulus to further endeavour. A piece of work that not only appears pleasing to the student but which earns the commendation of the teacher has far more beneficial effect than an ambitious attempt which has ended in failure.

In the case of theoretical instruction which accompanies a practical art there may be good reasons for adopting a chronological sequence; and this may be justified in spite of the fact that it may involve a breach of the maxim "from the simple to the complex". For instruction of this sort would not, as a rule, be given to beginners, and for older students, with well-stocked minds, the gradation of topics is of less importance.

We may summarize the content of this chapter in a few paragraphs:—

(*a*) The function of the teacher is *to train students to learn for themselves.*

(*b*) Subjects of instruction may be classified broadly under the heads of *knowledge* and *skill.*

(*c*) *Knowledge* is dual in character and consists of *experience* plus *belief.*

(*d*) There are certain old and well-tried maxims which are useful as general guides. These are: "That teaching should proceed (i) from the known to the unknown; (ii) from the more to the less familiar; (iii) from the particular to the general; and (iv) from the simple to the complex."

(*e*) In dealing with *skill* subjects the most useful maxim is the fourth.

Chapter II

HOW THE MIND WORKS

Having considered briefly the nature of knowledge and skill, and having seen how certain general rules can be derived, let us now try to understand how the human mind works. If anyone will look inwardly, and try to realize his mental state, he will find that he is conscious of continual flow of ideas—ideas about people, places, events, things—their shape, size, colour, and purpose, and other qualities. And in addition to these ideas about concrete and tangible experiences he will find himself now and again thinking about such abstract qualities as good and evil, love and hate, courage and fear, and other states or conditions that cannot be seen, heard, smelt, tasted, or touched.

He will observe, moreover, that the ideas do not as a rule occur at random. There is usually some sort of connection between them. They have been associated in his past experience, or in what he has heard or read. The idea of a particular person may be associated with an event and, probably, with a place. Two events may be associated because they occurred at the same time, or because there was a definite interval, say one year, between them. But these associations of time and place, which occur in everyday

life, are of less importance in technical teaching than those in which the ideas have a logical relationship—e.g. cause and effect, or a relationship of contiguity. For example, if a young engineering apprentice thinks of a lathe he is conscious of the whole machine, and then, as the general picture becomes dim, of the shape, size, material, and function of its various parts. Or if a cook thinks of a particular pudding, ideas at once arise as to the nature and proportion of the ingredients, and the method of procedure in making it.

Of the ideas of which we are conscious at any moment a few stand out sharply and clearly, and others, which are either just appearing or just disappearing, are relatively vague and indefinite. But the whole forms what we may call a mental picture.

Now this association of ideas provides an explanation of *memory* and *imagination.* If the group of ideas is one which has been presented to the mind on some previous occasion, the recurrence of the group is an act of memory. If the group is not one which has been presented before, the occurrence is an act of imagination. The new group may or may not be in harmony with experience. If it is not—if it is unreal, weird, fantastic—the appearance is rather an act of phantasy than imagination. But with this aspect the technical teacher is not concerned. What does concern him, however, is the fact that the more vividly, and the more frequently, a particular group is presented to the mind, the more likely is that group to reappear in the ordinary course of mental activity.

The fundamental process in training memory is repetition.

But this statement requires two qualifications. The repetition should not be wearisome. It should be at rather frequent intervals at first, and at longer intervals as time goes on. Nor need the repetition be complete. It is often sufficient merely to mention one idea, and the whole group then rises into consciousness. The object is to bring the group frequently into view, because the longer it remains out of sight the less readily does it appear. Knowledge which we use frequently is always at our command. Knowledge which we do not use frequently requires an effort to recover it from our mental storehouse.

The second qualification is that the repetition should be done by the student. The teacher should be content to give a clue—to suggest an idea in, or closely associated with, the group. It is the student's mind and not the teacher's that is being trained.

Many subjects provide their own repetition. Early facts and phenomena are so frequently required to explain later ones that very little formal repetition or revision is necessary. Fundamental principles are continually applied throughout the course in the solution of new or more complicated problems. This is particularly true of Mathematics, Mechanics, Physics, Chemistry. In Botany the technical terms which appear so formidable to a beginner become familiar with constant use. And with increasing familiarity their meaning becomes clearer.

Neither memory nor understanding are instantaneous mental processes. They require time, as a rule. When the writer was a small boy he had to learn a piece of poetry for homework. After spending most of the evening at it he was still unable to repeat it without a mistake. So he had to go to bed with the task, as he thought, unfinished. But, trying it again while he was dressing in the morning, he found to his astonishment that he remembered it completely.

Again, in regard to understanding, he was engaged some years ago in writing a chapter on wireless telephony. He had read a good deal about it and thought he understood enough to write a simple explanation in 2,000 or 3,000 words. And he began to write. For a time all went well, and then he found himself at a standstill. He could not go on. So he left it alone for a day or two. Then suddenly the way to explain the point which had troubled him flashed into his mind. At the first opportunity he continued the chapter, and made good progress until another difficulty faced him. The process of letting it alone for a few days was again followed, and with the same result.

The mind, in fact, often works subconsciously, and in this way knowledge acquires permanence, and understanding crystallizes out of chaos. The teacher should not be discouraged, therefore, if students fail to remember or to understand at the first attempt. Nevertheless, he cannot afford to rely too frequently on what is called subconscious cerebration.

The figures given on pp. 5–7 represent the total mind-content of a particular individual. But no one has the whole of his knowledge in view, as it were, at once. We are conscious at any one time only of the few ideas that occupy what may be called the "field" of mental vision. Ideas are continually passing into or out of this field, and it is only those in the centre of this field of which we are clearly and acutely conscious. Another way of putting it is to speak of a threshold of consciousness, and to regard ideas as continually rising above or falling below this threshold. Here again there will be a few prominently displayed and others more dimly and vaguely seen. The latter belong to what is called the margin of consciousness. The margin of consciousness is the fringe of the picture which is in the mind at any particular moment. The picture, with its fringe, may be "held" for a time and examined, and this involves effort. The minds of some people are so mobile, or so unstable, that they cannot "hold" a picture. They lack concentration. That is a personal quality, peculiar to the individual, and varying widely with different people. But within limits the power of concentration can be developed. The first essential is to shut out all distracting influences. A very delightful method of doing this was used many years ago by the late Mrs. M. E. Boole, in teaching Geometry. Having worked through a problem and drawn the figure, she would say: "Now girls. Put down your pens. Sit back. Fold your arms. Close your eyes. Make a picture." The girls then endeavoured

to visualize the figure. The writer has used a modification of this plan. Having given a description of a piece of country or a civil engineering work, he has asked the students to lean back comfortably, to fold their arms, and close their eyes, and then has described the country or the structure in a few short, terse sentences. The " word-picture " calls up into the minds of the students the main features of the scene. This rivets attention on essentials and facilitates both memory and understanding.

Let us consider what happens when a person *wishes* to remember something. The ideas are allowed to flow through the mind, each one as it appears being examined momentarily, and then permitted to pass on. Sooner or later one appears which, while it may not be the one required, belongs to the same group. That is " held ", and its associates gradually appear until the one which is sought comes into view.

This mental process is facilitated by the fact that the groups are not independent. They are associated with one another. An idea may belong to two or three or more groups. The idea which first arrests attention may not be followed immediately by the right group—by the group which contains the idea sought. But if the mind-content is well articulated—if the groups are properly and fully linked up with one another, the search will not be prolonged. This articulation or organization is secured by frequent cross-references, surveys, and summaries, in the course of the instruction.

The groups serve another purpose in the acquisition

and retention of knowledge. Their very existence implies that the mind dislikes odd ideas. A stranger can find no permanent home unless it can become associated with an appropriate group. Delay often occurs, therefore, until a suitable group appears. The mind is then said to *apperceive* the idea. The writer well remembers this view becoming current in this country. It was popularized by the late Mr. T. G. Rooper, H.M.I., in a charming essay called *A Pot of Green Feathers*. The subject was a child in a slum school who had never seen the country. She was shown a fern growing in a pot and was asked what she thought it was. Ferns were outside her experience, but their fronds reminded her of feathers. She knew feathers, because, in those days, all the women wore them in their hats. So she called it " a pot of green feathers ". She had no group or *apperception mass* for ferns. She had one for feathers. So she put it into that because, on the whole, it seemed to be appropriate.

The presence of these apperception masses in the mind renders it sensitive to the external world. Even a dog, lying apparently sound asleep on the hearth, will raise its head and listen if its own name is spoken in ordinary conversation. We notice things not so much because they are there as because we possess a number of ideas about them. We are apt to ignore what we see or hear if it does not fall readily into one of our groups, and we are apt to give undue prominence to matters in which we are specially interested. If a politician, a geologist, and a business man visit a

new country, the first will probably return with an immense amount of political information, the second with an equal accumulation of knowledge of the geology of the country, and the third man will have made special study of it as a market for his goods. A number of years ago the writer went to see a school laboratory in South Wales with three friends. One of the three was a geologist, another a chemist. As they were walking along a winding path the geologist suddenly stopped, and pointing to some stones which formed a margin, remarked: "Look! Those are erratics. They come from the north of England." Then, a moment later: "They must have been brought as ballast in a ship." On entering the porch of the laboratory the chemist stood still, and sniffed several times. "What on earth have they been making? I don't recognize it," he said. The geologist saw stones and the chemist smelt odours, which excited their curiosity. The writer and his third friend lacked the apperception masses which enabled the others to recognize the unusual.

People observe as a rule only what they have learnt to observe. There was a practice some years ago of endeavouring to train the observation of children by taking them out for country walks. Adam's remarks that "the pupil is to observe the note of the skylark, the scent of the violet, the form of the clouds, the colour of the primroses, the smoothness of the grass, the springiness of the turf. He is to amble along with the Five Gateways of knowledge wide open, and we

know that the mouth is one of them ".[1] And a little later: "The educator who seeks to cultivate observation by supplying materials to gape at, does not know the rudiments of his art."[2] The writer has on several occasions seen students quite unable to make observations in Chemistry because their knowledge of Physics was inadequate. Chemical changes are, in fact, only apparent through changes of state, density, colour, or the evolution of heat, light, or electricity, and these are physical phenomena.

The apperception masses again are responsible for *interest*. Interest is often regarded in a popular sense as something which is external to the mind—an object, an event, a phenomenon, or even a subject is said to be "interesting". In an educational sense interest is a fusion of what is *in* the mind and what is external to it. Some teachers confuse interest with curiosity. Boys are intensely interested in engines and mechanical appliances, but unless they know something about these things that is not interest in an educational sense. A teacher stated some time ago that he began his course in Heat by taking his boys into the laboratory and showing them the steam engine at work. In that way, he said, he aroused their interest. Another teacher deferred the visit to the laboratory until the boys were sufficiently acquainted with the phenomena of heat to render the visit profitable. It may be that a visit to a laboratory which involved few

[1] *Herbartian Psychology Applied to Education*, p. 139.
[2] Ibid., p. 161.

explanations and little thinking was a " soft option ". But there is something to be said for both methods.

In some cases the interest which a technical student displays towards a subject may be really directed to what the subject symbolizes—a career, or advancement in a profession. The interest of young women in cookery often arises when they become, or have prospects of becoming, engaged. The strong motive which brings students into part-time classes renders the teacher's task easier, in some respects, than it is in Elementary and Secondary Schools. He finds it less difficult to secure and to retain the attention of his students. But it is necessary, nevertheless, to keep in mind the relationship between the mind-content and new knowledge. This is particularly important in the case of adult students. They want to know, and to feel sure that they know. Interest, in the popular sense, they have in plenty. What they need is the link between the mind and the subject. The writer has on several occasions noticed the strained looks of a class when they have had a difficulty in comprehending the teacher's exposition. And he has also observed the looks of satisfaction when the explanation or solution has become clear to them.

Let us now summarize briefly what has been said about the way in which the mind works.

(*a*) There is a continual *flow of ideas* through the mind.

(*b*) These ideas occur in *associations or groups*.

(*c*) Usually these groups are, in content or

arrangement, such as have been presented to the mind on a previous occasion. The occurrence then is an act of *memory*.

(*d*) If the groups, in content or arrangement, differ from those which have previously been presented to the mind, the occurrence is an act of *imagination*.

(*e*) The more vividly a group is presented, and the more frequently reference is made to it, the more readily and the more frequently will it recur. This secures *retention* of knowledge.

(*f*) Neither memory nor understanding are instantaneous. Time is required, and the *mind works without conscious effort.*

(*g*) The groups are not independent. They are associated with one another, and *one idea may be a member of several groups.*

(*h*) The mind dislikes odd ideas, and in general a new idea can only be assimilated by absorption into an appropriate group. This is called *apperception* and the group which receives it an *apperception mass.*

(*i*) The apperception group thus renders the mind sensitive to the external world. Casual notice leads to *observation* when there are ideas inside the mind with which a new idea can be readily associated.

(*j*) In an educational sense, *interest* is a reaction between an apperception mass and a person, place, thing, quality, event, phenomenon, or topic.

The human mind is, of course, much more complex than this brief outline might suggest. Ideas are accompanied by feelings or emotions, and by the will to do, and these form essential parts of the mental process. But they are more important in the case of children than of the older students who require Technical Education. The latter attend voluntarily ; they are in earnest and therefore they are usually attentive and industrious ; and they have had ten years' experience of learning before they join Technical classes. The Technical Teacher is not very much concerned with the somewhat difficult problems that confront the teacher in Elementary or Secondary Schools. He can, at any rate, perform his task intelligently and effectively on a much narrower theoretical basis. No doubt he would discharge his duties still more intelligently with a wider and more detailed acquaintance with the theory of mental processes, and he would be well advised to extend his knowledge of the material upon which he has to work. But the purpose of this chapter is to provide the minimum which is necessary to explain or justify the practical methods which comprise the rest of the book.

Chapter III

GENERAL METHOD

Teaching is both a science and an art. It is a science because it involves the use of scientific principles, and it is an art in that it is something to be done. So true is the last statement that it may be said that the only way of learning to teach is to teach. Nevertheless, the learner who keeps before him the scientific laws upon which good teaching is based, will find that his progress in the art is more rapid and more satisfactory than it would be if no scientific basis were available.

In the last chapter an outline of the more important activities of the mind have been given, and we shall proceed now to consider a general plan of treating any subject for which the teacher is responsible. But as teaching is so largely a matter of personality and habit it is necessary to warn the reader against adopting any set plan until he is sure that he thoroughly understands it. He would be well advised, especially if he has been teaching for some years, to proceed tentatively, and to adopt this or that portion of the method which seems to him easy to adopt, and likely to be beneficial to his students. Moreover, he should make the method his slave, and never allow it to

become his master. Conditions vary in different classes. They vary from year to year as each group of students comes up for instruction. Special and unexpected circumstances require modification of the general plan. To meet these variations elasticity of mind is necessary. But the teacher who has the most complete grip of the whole plan will be the most capable of dealing rightly and adequately with the exigencies of the situation.

If the reader examines any subject he will find that it has a structure. No knowledge-subject consists of a number of independent ideas. The ideas are in groups like those which exist in the mind, and these groups have points of contact or overlapping which confer coherence and unity to the subject as a whole. Similarly every *skill* subject consists of groups of operations, bound together by a common method, or by the use of a common material, or by a common purpose. And these, again, have points of contact and areas of overlapping. These are obvious facts to anyone who has surveyed a subject, and has endeavoured to understand the relationship of one part to another. They will be most apparent to anyone who has had to draft a syllabus. It is an illuminating experience to set out a synopsis of a subject, displaying the order of treatment, and it is in some respects unfortunate that most teachers have to work to syllabuses which someone else has drawn up. It is still more unfortunate that they sometimes fail to recognize that the syllabus supplied to them is in most cases an examination

schedule only, and that it is not always suitable as a plan of treatment in class.

If every subject has this group structure, and if the organization of the human mind is a group organization, the syllabus which the teacher uses should emphasize the groups of ideas or operations. No subject can be divided into twenty-five or twenty-six independent lessons without placing difficulties in the way of the learner. Such a division may be dictated by the needs of a school time-table, but *the unit of teaching is the group, and not the single lesson.*

The groups, or divisions of a subject for the purposes of teaching, are called *sections*, and the first step which every teacher should take is to set out the subject in sections without reference to the time which each section will require. The next step is to allocate so many lessons to each section, leaving two or three nights over in order to provide an opportunity for fuller treatment or repetition if that should appear to be necessary.

It is desirable that in part-time classes a syllabus drawn up in this way should be given to every student. By looking at it occasionally he will acquire a picture of the scope and structure of the subject, and that will help him to form the correct associations and relationships of the constituent ideas or operations. Moreover, as absences during the session are inevitable, the syllabus will indicate to him what he has missed, and it may enable him to repair that omission by reference to a text-book. For the most part students

in part-time classes have a strong motive for attendance and a real desire to learn; and they appreciate very much any provision which lightens their task.

It is also an advantage to emphasize the structure of the subject by embodying it in the note-books. As the notes on each section are completed a leaf of the note-book may be folded diagonally to mark the division between the sections before and after. Another plan is to insert a sheet of coloured paper to mark the divisions. Thus, every time the note-book is used the student is reminded of the general arrangement of the facts, phenomena, and principles of the subject. This facilitates the organization of his mind-content on the same plan, and he realizes, perhaps unconsciously, that what he has to keep in mind is not a relatively large number of small detached groups of ideas, but a relatively small number of large groups. The plan contributes materially to the unity and coherence of his knowledge.

There may be differences of opinion as to the extent of the subdivision in any given subject. It would be possible in some cases to divide a whole session's work into only two or three sections; but it would not be desirable to do so. Of, say, seven groups of ideas—*A*, *B*, *C*, *D*, *E*, *F*, *G*—*A*, *C*, and *F* may be more closely associated with one another than any one of them is with one of the other groups. In that case *ACF* may be regarded as one section, and *A*, *C*, and *F* as sub-sections. Generally, a section should occupy from three to six lessons. If the sections are shorter the student

has to remember too many semi-detached ideas or small groups, and he is little better off than he would be under the tabloid method of one independent lesson a night. As a rule it will be found that six to eight sections in a session's work is a convenient arrangement.

We shall now proceed to consider the formal treatment of each section and, for the present, we shall confine our attention to the acquisition of knowledge rather than skill.

It will be clear from what has been said about apperception masses in Chapter II that the acquisition of new knowledge is determined by what is already in the minds of the students. The first step, therefore, is *Preparation*, and this will be followed by *Presentation*. The teacher will know that the ideas to be presented cannot be assimilated unless the students have in their minds the appropriate group or apperception mass. They should possess this through their previous education, through attendance at that or another class in the course, through ordinary everyday experience, or through their special experience in their occupation. But whatever they *should* have done it is incumbent upon the teacher to ascertain whether they *do* know what they are expected to know ; and if they do not, to supply it himself.

For example, it is not much use trying to explain the Kinetic Theory of Matter to students who have no notion of Kinetic Energy. The way in which a steam engine works can only be understood properly by

students who have certain knowledge of geometry, mechanics, and heat. The teacher of Gas Engineering who wishes to deal with the removal of ammonia from coal gas will require his students to be familiar with Dalton's Law of Partial Pressures. To understand the behaviour of a magnetic field upon a suspended needle a student requires to have learnt the parallelogram of forces. These examples, taken at random, could be multiplied *ad infinitum*. And yet, unfortunately, they indicate errors that frequently occur.

They are common enough, too, in daily life. Adams mentions the case of a man who was quite unable to understand the arguments in favour of the rotundity of the earth, because he had never learnt geometry. And many people are mentally blind to the phenomena and events around them because they do not possess the requisite apperception masses.

To ascertain whether his students possess the requisite ideas the teacher may question the class—and he may be so unfortunate as to pick upon those that *do* possess them. Or he may set a question involving those ideas for homework a fortnight in advance. That gives him time to arrange to supply them if necessary. The students may display some acquaintance with the subject, but their information may be hazy or inaccurate. This haziness must be removed and inaccuracies must be corrected. Whether the information has to be supplied *de novo*, or merely clarified or corrected, there is room for grip and

judgment in deciding how to achieve the end without consuming too much time.

The necessity for this arises all too frequently. Under the grouped course system the student receives instruction from two or three teachers, and in some cases a teacher, say, of mathematics, has not realized the requirements of his colleagues. These are circumstances which render omissions almost inevitable. Students in a particular industry may be so few that they cannot be provided with separate classes except in the main subject. For instruction in ancillary subjects they are obliged to attend classes designed primarily for students in other industries or occupations, and, however effectively this class serves its original purpose, a student finds that sufficient emphasis is not laid upon those parts of the subject which are most useful to him.

It may be noted that this first step, Preparation, frequently defines the aim of the section in that it indicates what new knowledge is to be acquired. Its importance cannot be too strongly emphasized. It means all the difference between successful and unsuccessful teaching, between progress and stimulus on the one hand and failure and discouragement on the other. And these apply to the teacher as well as to the student.

When Preparation has been assured, the new knowledge may be Presented—that is Step II. The word "Presented" does not mean that the new knowledge is necessarily to come from the teacher. It may be

Presented to the student's mind as a result of his own activity. *The Media of Presentation* are lecturing; discussion; private reading in class or at home; the study of drawings; calculations; experiments; the examination of actual examples of mechanical devices, models, or specimens; or visits to works. These are the *devices* of teaching, and will be considered in detail in the next chapter. Here we are concerned with them merely as the various ways in which new knowledge may be acquired. Each of them has its special usefulness, and the extent to which each is employed depends partly upon the idiosyncracies of the teacher, partly upon the nature and standard of the subject, and partly on the age and type of student. But an effort should be made to use a variety, especially in classes which last for more than an hour. Monotony is to be avoided as far as possible in all instruction, and especially in classes attended by students who have already done a day's work. On the other hand, changes should not be too frequent. A course should be steered between monotony and restlessness. And any change in the course of a lesson should as a rule be one of the medium rather than one of the subject. The mind seems to possess inertia. When the flow of thought is running freely a strange idea, involving a change in the direction of flow, is resented. It interrupts the flow and irritates.

If the teacher does permit himself to indulge in a digression he should be sure not only that it is appropriate to the subject, but that it will be acceptable to

the minds of the students. Not long ago a teacher was lecturing to an advanced class in Organic Chemistry and was dealing with Petroleum. He proceeded to talk about the difficulties which had arisen with Soviet Russia. Before he had gone very far into this matter, he was interrupted by one of the students, who said: "Excuse me, Mr. X., we came here to learn Organic Chemistry and not to hear your views on the International situation."

We may suppose that in the course of two or three weeks the students have acquired a number of facts or ideas. The next step—*Abstraction and Formulation*—is to survey the facts and express them in a general law or principle. Thus if experiment has shown that certain gases expand by 0·0036 of their volume at 0° C. for each degree centigrade rise in temperature, and if on the authority of the teacher the students can comprehend this as a universal law for gases, the result can be expressed in a verbal statement and also in a formula. Or, if a number of students have measured the diameters and circumferences of different circles, their results may be collated, and the law that the circumference equals 3·14 times the diameter can be stated. Abstraction and Formulation represent Step III.

We can here find a reason for not making the sections too small. No student can survey, compare, contrast, and classify facts without having a sufficient number of facts upon which to operate. It is a mistake to ask, or to expect, students to reason without adequate

material, and the attempt should not be made too early in a subject upon the study of which students are entering.

The general principle or formula can now be applied to the solution of problems or the explanation of phenomena. It may have been based on the study of a limited number of particular cases, but every time it can be successfully applied to a new set of data or conditions strengthens belief in its truth. The step is called *Application.*

It may be remembered that in Steps II and III a general rule, or law, or principle, is *inferred* from a study of individual cases; and in Steps III and IV the solution of an individual problem, or the explanation of a particular phenomenon is *deduced* from the general rule, which is assumed to be true. These two processes correspond to two well-known logical methods—the Method of Inference and the Method of Deduction. Men reason from the particular to the general and from the general to the particular. So the general plan of treating each section embodies both of the chief methods by which the human mind arrives at rational conclusions.

The Four Step Method as outlined above is based on the teaching of J. F. Herbart, a German philosopher and educationist, and is consequently known as the Herbartian method of teaching. It is applicable in general only to subjects like Practical Mathematics, Mechanics, Physics, Chemistry, in which general laws can be inferred from the study of individual cases.

Many subjects do not lend themselves to this treatment. They are descriptive rather than logical. But though the knowledge presented cannot be abstracted and formulated, it can be summarized. Step III then becomes a Summary, and Step IV disappears. This modification has to be made in Engineering Drawing, Building Construction, and branches of Applied Science and Technology, such as Metallurgy and Gas Engineering. For example, the class having studied several machines designed for the same purpose, will compare and contrast them, classify them according to some important feature, and then record briefly the result. These mental activities of comparing, contrasting, rejecting unimportant details, and abstracting essential features, afford training in observation and the exercise of judgment.

Where a large section has been divided it will be clear that the four (or three) step method should be applied to each sub-section. Furthermore, *when the last subsection has been completed the whole section should be subjected to the same treatment.* In this way a large and complex section which the students would be unable to grasp if it were presented to them originally as a whole, is brought within their capacity by building it up gradually.

The writer recalls an interesting case in which this difficulty occurred. A weak class of youths who had left school some years were receiving a lesson in algebraic factors. The teacher showed four typical forms, and then set the class some exercises. Not one

student could work a single example. It was suggested to the teacher that a few examples should have been worked by the students on each form as it was presented. He tried the plan and before the end of the evening the students were able to work miscellaneous examples with some ease.

In reviewing the method it may be remarked that Step II—Presentation—is always adopted, because no teacher can avoid it. Step I is sometimes omitted either because the teacher is not aware of its importance or because it is often troublesome. Step III is not used as freely as its importance demands. On it depends not only the clearness and definition of the students' knowledge, but also the organization of that knowledge. In order to secure a well-articulated mind-content there ought to be frequent reviews or summaries. Without formal method these are omitted or introduced fortuitously. Under the control exercised by formal method they occur at appropriate stages of the instruction.

CHAPTER IV

THE DEVICES OF TEACHING

Whether the teacher adopts a general plan or no plan at all he is compelled to use certain Media for securing contact with the minds of his students. These Media, as we called them in the last Chapter, or *Devices* as we shall call them in this, are Lecturing; Discussion; Reading, Talking, and Writing; Illustrations—Verbal, Pictorial, Experimental; the examination of models or specimens; visits to works. We shall proceed to consider each of these in the order given.

LECTURING

We may include under this head not only the formal lecture, in which the students do nothing but listen and take notes, but also the less ambitious and often more casual talks, descriptions, and explanations which most teachers employ. The essential element in lecturing is lucidity. What the lecturer says must be heard without strain by every person in the room. This is especially important in the case of young students. A man or a more advanced student will make an effort to hear what is said; very often a boy will not. On the other hand the voice should not be raised unduly, both for the lecturer's sake and on

account of the irritation produced in listeners who are already tired after a day's work.

Every word should be spoken clearly—not gabbled, and the final consonants should be sounded. If that is not done the word thins out: it is never really completed. The writer has heard teachers who have carried this dictum to excess. It is not necessary to speak in a pedantic way. It is quite easy to speak naturally and yet utter each word clearly. And a teacher who is not sure of himself in this respect should practice in the privacy of his chamber, or out in the country where he can be sure that there are no listeners.

The clear enunciation of every word is not more important than the arrangement of speech in phrases. It is the phrase, and not the word alone, which conveys meaning. A word without its context is a strange thing. Think of a word. Examine it. Ask yourself why it is spelt in that way and what it really means. You will find it extremely curious. Yet put it into a phrase and it seems to be perfectly natural and devoid of strangeness.

The writer once heard a teacher dictating to his class from his own notes. He read out one word at a time, and because there was no immediate context it was often difficult to recognize the word. But—if the teacher—had read his notes—in phrases—they would have been—much easier to follow. Notice the spacing there. In this particular case students were continually leaning aside to look at one another's books for a word which they had failed to identify.

When loudness, word, and phrase have been mastered, there remains orderly sequence of ideas. The stages or steps of the description, explanation, or argument, should be clearly marked out, and should gradually be built into a clear and coherent whole. It is a good plan for a teacher to write some of his instruction out beforehand; and if necessary to rewrite it until he is sure that it is as simple and as precise as he can make it. This process helps to clear his own mind. But what is written in this way should not be read. A man has to be a very good reader to render that method stimulating to the class. Nor should it, as a rule, be dictated. Dictation is justified only in the case of fundamental laws, definitions, and important statements in which the precise words or form are necessary in order to convey an exact meaning.

There is no advantage in requiring students to make their own definitions, except as an exercise. Having been put into a particular form by a writer who has a relatively full and complete knowledge of the subject, it is hardly likely that a student will improve on it. But these crystalline statements, however clear they may be to the mature student, often convey very little meaning to the beginner. A student will commit any number of verbal statements to memory without really understanding them. He has often too little knowledge of the subject to appreciate the range and implications. The statement of laws and definitions should, therefore, be accompanied in many cases by explanations or descriptions. Laws and

definitions are dry bones; they need some clothing to make them live. A definition is the simplest and most precise statement that can be made about a thing—using the word "thing" in its widest sense. A description is not necessarily less accurate, but it *may* be more vivid or picturesque. Thus a straight line may be *defined* as the shortest distance between two points. D'Arcy Thompson *described* it as "the path pursued by an ecclesiastic with a bull behind him and a bishopric in front".

On the other hand, explanation should not be overdone. It should not be carried beyond the point at which it has achieved its purpose, lest it bores, or even confuses the students. The students become like the little girl in *Punch* who said: "I think I could understand, if only you wouldn't explain so much."

However clear and orderly the teacher's exposition may be, he must expect to be misunderstood. The capacity of human beings for obtaining false impressions is amazing. It is almost impossible for a man to speak to an audience of a dozen people for twenty minutes without someone failing to catch his meaning. Sometimes this is due to a relaxation, or a diversion of attention, so that a portion of the speaker's remarks is not heard. In other cases it is due to the fact that the same word or phrase uttered in the presence of different people conveys different meanings. What each listener apprehends is not the idea in the lecturer's mind but a combination of that idea and one of his own apperception masses. As the minds of

people differ in content to almost as great an extent as form and feature, the idea suggested by a word or phrase may fall into the wrong group, or into a group markedly different from its associates in the mind of the speaker. This is what occurred when a boy was asked why the days were longer in summer and shorter in winter, and replied: "Because heat expands and cold contracts."

It is often desirable to repeat important statements once or twice, and this should be done slowly and with emphasis. Sometimes the repetition or, at any rate, a second repetition, may be limited to a few short, terse phrases referring to the salient points. Not only does this plan reduce the likelihood of misunderstanding in regard to the particular matter under discussion, but it gives perspective and form both to the lecture and to the subject. A "flat" exposition, without variation of pace, tone, or emphasis, is apt to be dull, insipid, and uninspiring.

The principal advantage of lecturing is that it enables the teacher to make full use of his personality. If that is sufficiently strong or attractive he commands the attention of his students, and dominates their minds. He controls the flow of their thoughts, and creates in their minds, as far as that is possible, the same mental picture that he has in his own. And if he has, in addition to personality, a pleasing voice, and adequate command of language, an orderly mind, and a supply of vivid and effective illustrations, he can be very successful—with older students. Younger

students, however, lack the power of sustained attention to benefit fully from lectures. Moreover, they are too apt to misunderstand or only partially understand.

But even with older and more advanced students the formal lecture has disadvantages. There is a difficulty in covering the whole of the ground. It is rare, indeed, to meet a man whose exposition is as fluent and orderly as that of the printed page. There are many who, if they could hear a phonographic record, or even read a verbatim report of their own lectures, would either give up teaching or adopt devices more appropriate to their own ability, and more effective in regard to their students. Nor are these all to be found in Technical Schools.

Perhaps the most serious objection to the formal lecture, however good its content and delivery may be, is the fact that it leaves the students inactive. This is undesirable for young students with an undeveloped capacity for sustained attention, and for all students in evening classes. They are often tired, and need stimulus in order to enable them to concentrate. Unless they are called upon to take some active part in the process of learning their minds wander, and they miss a good deal of what the lecturer is saying. If, however, they are liable to be called upon to answer a question, make a calculation or drawing, examine a model or specimen, their minds are kept on the alert, and their attention is retained.

On the whole, therefore, the formal lecture should

not dominate the teacher's method. Some systematic, orderly exposition is essential. The amount must vary with the nature of the subject and the age and standard of the students. But it should be regarded only as *one* of the means which the teacher has at his disposal for presenting a description, an explanation, or an argument.

Reading, Writing, and Talking

We have grouped these three devices together because they embody the activities of the student which involve the use of language. The teacher may lecture, but the students have to read, talk, and write ; and it is the teacher's business to stimulate and direct those activities in such a way that the student does not merely learn the subject, but forms habits of study which he can carry out into the world beyond the school.

The precise effect of each is well expressed in Bacon's famous aphorism : " Reading maketh a full man, Talking a ready man, and Writing an exact man." To produce richly stored minds, ready minds, and minds which are capable of precision of thinking, reading, talking, and writing cannot be neglected. But it is important to observe that behind each form of activity lies *thinking*, and language is the medium by which thought is expressed.

The most obvious use of reading is suggested by the remark that it is rare to meet a man whose speech has the fluency, order, and, it may be added, the verbal economy of the printed page. In most subjects there

are excellent textbooks in which the facts, processes, and phenomena are described and the arguments are clearly set out. A great deal of the book is concerned with ordinary straightforward information, and there seems to be no reason why the teacher should endeavour to repeat it all in class. If the students are required to obtain this information for themselves, the teacher is left free to amplify the book where it is deficient, to correct it where it is wrong, and to stress those aspects which are of greater importance. Incidentally he may find that the students have missed a main point in their reading, or have misinterpreted what the book says. They may not be so bad as the boy who, reading that Hydrogen was not found in the free state, concluded that it need not be sought in Ireland ; but it is very easy for young students to read a chapter or half-chapter and know very little about what they have read.

It is such unfortunate experiences that lead some teachers to place very little reliance upon the students' private reading. They complain, often quite rightly, that the students do not know how to obtain information from books. But if their learning is not to cease when they leave the Technical School they must be taught *how* to use a book ; for books or technical journals will be the only means by which they can keep in touch with the development of the industry in which they are engaged. How, then, should the teacher proceed to provide this training ?

In the first place he should make it clear to the class

that he will expect them to have read a certain portion of the book before they come the following week. He should try to convince them that the business of learning requires the co-operation of the teacher and the students, that each has to contribute to the process, and that it is to their benefit that they should do what he asks them. He may point out to them the advantage of being already familiar with certain technical terms; for if these are introduced into a description or an argument for the first time, they distract attention from the principal features or the main issues. And he may add that he wishes to devote the time at his disposal to the amplification or correction of the text-book, and to emphasizing important facts or reasons that are liable to be missed.

In the second place, the *exact* portion of the book should be specified. If this is not done young students, and some older ones, will read discursively, and will be very little better prepared for the following week's work than if they had never read at all. The more definite the teacher can be, the more effective will be the plan. He may even emphasize the importance of particular pages or paragraphs. That will be welcomed rather than resented. Most people like to have their work arranged for them, and any evidence of care and thoughtfulness on the part of the teacher is sure to awaken a ready response.

So far we have assumed that the students *know how* to read for information, though it has been pointed out that they are liable to miss something or to

misinterpret the statements in the book. The plan encourages the student to use a book, reduces the amount of straightforward information the teacher has to give, saves his time, and enables him to make his instruction more thorough and complete. We have now to consider how less well-prepared students can be trained to use a book.

This can be most satisfactorily accomplished by requiring the students to work exercises which *necessitate the use of a book.* There are six types of exercise which lend themselves to this purpose :—

1. Summary.
2. Comparison.
3. Contrast.
4. Comparison and contrast.
5. Write down what you have not understood in the chapter or half-chapter you have read.
6. A series of three or four questions.

In the first the students are to look through a chapter or half-chapter which they are supposed to have read, and to write down the main points briefly. Or a summary can be made of several chapters. The second exercise involves setting out points of similarity, the third points of difference, and the fourth points of both similarity and difference. These three exercises are applicable to a wide range of subjects because comparisons and contrasts can obviously be made between persons, places, events, things, processes, and phenomena. And many students are not able to

answer questions of this sort without reference to the book. The fifth exercise is self-explanatory. The sixth is applicable to many chapters which do not provide opportunity for summaries, comparisons, or contrasts. The short paper consists of questions the answers to which are the salient points in the portion of the book set for reading. Clearly this directs the attention of the student to these points. The reader will appreciate the fact that these exercises constitute a valuable training in note-taking. The student acquires the habit of *looking* for the really important facts or ideas, and it is an easy stage from that habit to the habit of *listening* for the salient points in a lecture.

It is neither necessary nor desirable that the student should be informed of the process to which he is being subjected. The object is to form habits of critical reading in order to extract the " essence " of the book, and habits are most easily formed unconsciously. As we quoted in Chapter I : " The centipede was happy, quite," etc., and there is no need to confuse the learner by reference to his mental processes.

The method was adopted many years ago in a number of Preliminary Technical Classes. Two hours a week were devoted to English, and there was time for considerable elaboration of the exercises. This is obviously impossible in Technical Classes. Nevertheless, the teacher can do much to compel students to adopt correct habits of study by the suitable choice of written exercises. If he does that he is fulfilling the function allocated to him in the first chapter.

In the Preliminary Technical Classes to which reference has been made, the reading and exercises were done in class. In Technical Classes in which, as a rule, each student has a textbook there is no reason why some, if not all, should not be done at home. In any case Homework should be an essential part of the general method. The very common plan of picking up a textbook at the close of a lesson, and selecting three or four questions at random from the list at the end of one of the chapters, has nothing to recommend it. To the student it appears to be what is an extra task for which he can see little reason. But if it is bound up with method, if it is associated with one of the four steps, then it at once acquires a meaning and a purpose, and adds considerably to the value of the instruction.

It is a little curious that the Homework which is set consists, as a rule, merely of written exercises. There may be a general exhortation to read, but it is written exercises which are specifically required, and for which, alone, marks are awarded. While there may be good reasons for giving the students practice in the solution of examination questions, there is ample opportunity for training them also in the use of a book.

As has already been indicated, the teacher would be wise to consider the purpose which homework can serve in each of the four (or three) steps of General Method. It can be used as part of Preparation. The students can be required to look up and, if considered desirable, answer questions on some part of the subject which is essential for the proper assimilation

of the new knowledge which is to be presented to them. It can be used, as we have shown, as part of the Presentation. Some of the new knowledge—the informative part—can be obtained by the student from his textbook. Step III—Abstraction and Formulation—are better done under the teacher's guidance—at any rate with elementary students. If a Summary only is involved that forms as a rule an easier exercise. Most of the Homework which is set to-day falls under Step IV—Application.

Just as teachers complain that students have not learnt to use a book, so, too, they complain that students cannot express themselves. This is used as a justification—or an excuse—for dictating notes. This practice condemns them to one of the most menial mental tasks that could be devised. The students are less active intellectually than if they were listening to a formal lecture. All they are doing is listening to words and phrases which fall from the teacher's lips, and writing them down. They are rarely *thinking* about the subject.

The close and intimate association between knowledge and language cannot be too strongly emphasized. There are some kinds of knowledge which can be expressed most concisely and clearly in mathematical symbols, or by a drawing ; but there is no department of knowledge that cannot be expressed in words. And as language is the main link between the mind of the teacher and the minds of his students, the necessity for training in speech and writing cannot be ignored.

The Technical Teacher may say that it is not his business to teach English, but so long as he communicates with his class in English it is not easy to see how he can repudiate the obligation.

Moreover, the obligation can be met without expenditure of a great deal of time. He can set a simple question, requiring a simple answer, to be worked in class or at home. From the answers he obtains he can select one and write it on the blackboard. Then he can ask the students to say whether the writer of that answer has said exactly what he meant. Has he used the most suitable word and the right phrase? Would his meaning have been clearer if he had put the answer in another way?

As an alternative to that exercise, two selected answers may be written on the blackboard, and the students asked to say which they prefer, and why? A further alternative, adapted to younger students, is to ask the boys to write their answers on sheets of paper, exchange the sheets, and then state their criticism of any answer that seems to them to be wrong or capable of improvement. This method, however, needs to be used skilfully even with younger boys. In a class of older boys or men there are always some who are too sensitive to permit of the plan being adopted.

It will be understood that what is here being developed is a critical habit of mind. As it is easier to recognize the mistakes made by others than the mistakes one makes one's self, the criticism is first

directed to something which someone else has written. In that way the student becomes familiar with the kind of mistakes which *are* made, and he becomes more alert to discover mistakes in his own work. Until this stage of self-criticism is reached very little improvement in power of expression can be expected.

When considering the use of the textbook this training in a critical attitude of mind was implied. If the teacher expresses his intention of amplifying or correcting any portion of it, the student is impressed with the fact that textbooks are not infallible. If the truth is to be obtained from them they need to be read critically. That means they are to be read thoughtfully, not carelessly. Statements and arguments are to be examined, not so much to detect defects or flaws, as to ascertain precisely what they mean.

Again, the passage in a book may sometimes be used, instead of a student's answers, as a subject of class discussion. Occasionally a paragraph is badly arranged, and it is an interesting and profitable exercise for the students to rewrite it. Some books are out of date, and the rewriting of a paragraph or a page in accordance with recent facts or modern ideas is an act of high adventure for more advanced students. One who attempts this and earns the commendation of the teacher is stimulated and inspired ; he acquires a new sense of responsibility and a new confidence which raise him almost, if not quite, to the plane whereon resides the unknown god who wrote the book.

The mere act of writing is of considerable aid to

the memory. Anyone who wishes to retain a saying, or an anecdote, or a story, or a fine passage, or a scientific statement pregnant with meaning, should write it out a few times. The muscular activity involved seems to deepen the impression on the mind. Moreover, the mental effort of endeavouring to say what one means, to describe a machine or a phenomenon, clarifies and sharpens the mental picture and leads to better understanding. One of the few books available to the writer, when he was a boy of ten or eleven, was a copy of Martin Tupper's *Proverbial Philosophy*, and a single line of that has always remained in his memory :—

> "To read, write ; to remember, write ; to know thine own mind, write."

What has been said about books and writing implies discussion, and discussion means that questions and answers must pass backwards and forwards between the teacher and the class. This not only keeps the students alert, but it is the only way available to the teacher (apart from Homework) of ascertaining the extent to which they are profiting from the instruction. Intelligent questioning, neither too much of it nor too little, is probably the best test of a teacher's skill. It is not always easy to put the question in the right way, or to interpret the answer. A wrong answer is as valuable as a right one. The teacher must endeavour to look at the question from the student's point of view, and try to discover the cause of the wrong answer. Unless he can do this he cannot identify

the nature of the error in the student's mind. A wrong answer needs to be pursued to its source, and the teacher would be well advised occasionally not to stop putting the question when he has obtained a correct answer, but to question a few more students in order to bring out any misapprehension if it exists.

In this aspect of his work the teacher will probably meet with two types of mind that present difficulties. One is the type that cannot readily form mental images " in the solid ". The mind seems to be " flat " : it can often visualize quite well plane geometrical figures, but it cannot make pictures in three dimensions. Such students have great difficulty in understanding, say, a magnetic field, the relations of the magnetic, electromagnetic, and electrostatic forces, or a structural formula in organic chemistry. There seems to be no particular relation, in the same individual, between the capacity for dealing with plane and solid shapes. In young students the defect can be removed to some extent by handling and drawing solid objects. With older students not much can be done in this way.

The other type of mind is the superficial. The mind seems to be like a shell which is quickly saturated and can then assimilate no more. The student thinks he understands, because he never sees the difficulties. He is generally more ready than anyone else in the class to answer questions—and just as frequently he is wrong. Such minds can be improved, within limits, only by careful individual tuition.

To return to questioning. Unfortunately a question

cannot be put to every student, and the practice, though of the highest value, is liable to leave wrong impressions undiscovered. Some difficulty arises occasionally from a disinclination to answer questions. There are students who will answer more readily in class, and others who will only respond when they are approached individually in the laboratory, drawing office, or workshop. It is a matter of temperament, and full allowance must be made for it in teaching practice.

It is sometimes maintained that answers which consist merely of "Yes" or "No" should not be accepted; but that is a rather pedantic view. It may be desirable to know generally whether the class is assimilating the instruction or meeting with difficulties, and then perhaps a simple affirmative or negative will suffice. With older and advanced students some reliance can be placed on an answer of this sort. But it is desirable to avoid such a question as "Is that clear?" or "Do you understand that?" with a young class. In all probability they are not quite sure whether they understand it, or they may think that they understand it. It is safer, therefore, to put such a question that the answer reveals to the teacher whether they do or do not understand.

The ability to answer questions clearly and precisely has a value outside the classroom. It is a frequent requisite in daily life. It is desirable, therefore, to train the students deliberately in this art. They may not always be able to express what they know, but

it is pretty certain that they know what they can express.

The teacher will find that oral and written work reinforce one another to their mutual advantage. But he should constantly bear in mind that both arts are in the main imitative, and so far as the subject of study is concerned, he is their model. It behoves him, therefore, to exercise a jealous control over his own tongue. Raciness of speech no doubt adds to the liveliness of a lesson, and this is an advantage in the case of students who are tired; colloquialisms perhaps create an atmosphere of familiarity, and destroy the austerity of a formal discourse; but the teacher of science, in particular, should ask himself to what extent he can indulge in these practices without sacrificing that precision of language and thought that scientific studies involve. He should ask himself, moreover, whether he cannot provide the student with worthy examples of simple and lucid English. Have I used the correct word, the happy phrase, a logical sequence of ideas? Have I expressed myself so simply, so clearly, and so vividly, that the meaning of what I have said or written FLASHES into the mind immediately the words are heard or read? These are questions which the teacher should frequently put to himself if he has his own and his students' interests at heart.

To a large extent these are matters of general education, personality, and temperament. The teacher comes to his task with a certain endowment, which

it may or may not be in his power to modify. It is all to the good if he recognizes, and thinks in all seriousness on, the nature of his obligation.

ILLUSTRATION

It is almost a truism that all teaching requires adequate illustration. This may take three forms—*verbal*, *pictorial*, and *experimental*.[1] Verbal illustration describes something which is familiar or easily understood in order that the student may the more readily or the more fully comprehend something which is unfamiliar or difficult to understand. The mental process is very often one of analogy—the comparison of two similar mental pictures. It explains the unknown by analogy with the known.

Thus, temperature and electromotive force may be illustrated by comparing them with the effect of differences of level on liquids. The familiar flow of water, for example, from a high level to a low level, helps the student to understand the flow of heat from bodies at high temperature to bodies at low temperature, or the flow of electricity from bodies at high potential to bodies at low potential. Analogies of this kind cannot in many cases be pushed very far, because they are not strictly accurate, but they serve a useful purpose in the early stages of a subject in helping the student to form some sort of picture. The teacher who is interested in theory will observe that

[1] There is also numerical illustration, but this hardly needs to be discussed.

this form of illustration consists in using the apperception mass concerned with liquid flow to assimilate similar phenomena in heat or electricity. He will observe, further, that it is using a concrete example to explain an abstract phenomenon. Many illustrations of this type are mechanical analogies to explain the unseen and intangible.

Another kind of verbal illustration is a particular case of a general law. This book contains quite a number of examples. The mind grasps particular cases more easily than it conceives of a general law, and the nature and significance of the law are not obvious because the student has not in his mind a sufficient number of the particular cases from a survey of which the law has been abstracted and formulated. Every additional particular case presented to the mind not only adds to clearness with which the law is understood, but also helps to establish its general or universal application.

It may be noted that the first type of verbal illustration belongs to Step II of the formal method. It is concerned with the difficulty which students have in assimilating new ideas. The second type belongs to Step III. It is not, in the proper sense of the word, application, though it may come very near to this. Rather is it that kind of explanation which we have pleaded, on pp. 37–8, should accompany every definition or statement of wide significance. The development of generalizations is a very important aspect of teaching. A general law covers all individual

cases in which the conditions are similar. The mind, therefore, need only retain the law; it need not be littered with fragments of knowledge upon which it is based. Assimilation of the law gives the mind of the student a wider capacity or range. The more quickly he can be trained to grasp general laws the more completely organized will be his knowledge, and the more rapid his progress.

We may give two examples of the kind of generalization which is contemplated. It is just as easy in Mechanics to teach the principle of moments as it is to teach the so-called principle of the lever, which is only a special case. And having assimilated the larger principle the student will be able to apply it to a wider range of problems than the lesser rule. Again, in Chemistry the student should learn that hydrochloric acid is produced by the action of sulphuric acid on practically any chloride, and not merely common salt, as the method given in the textbooks is apt to imply.

In dealing with some topics illustrations may well be anecdotal, or in the form of personal reminiscences. The former may add an element of lightness and gaiety—or even tragedy, to the instruction, and personal experiences confer upon the teaching a sense of a reality. Students always like to obtain their knowledge from a man who gives them the impression that he has made a subject his own, and that he is not merely conveying to them what he has read in a book.

The second kind of illustration is that which involves

the use of pictures, diagrams, lantern slides, or drawings made on the blackboard. Of these the last-named are the most effective because they grow up under the eyes of the students. But they require skill to make them neatly enough to be copied, and a complicated drawing takes up time that cannot always be spared. In some classes a great deal too much time is spent on this work. Wall diagrams or lantern slides are essential for showing details on a large scale, and the diagrams should, as far as there is room, always be displayed. Every time the student looks at the diagram it will become more firmly impressed on his memory. This is the more necessary if the diagram is a complicated one which requires to be analysed, or examined closely part by part, to understand it.

It is rather curious how anyone should fail to realize this condition. And yet there was a teacher not many years ago who always kept his diagrams covered with a curtain until he reached the point at which he wished to refer to them. They were arranged one behind another on an easel, and, at the psychological moment, the upper one was dramatically unveiled. If this diagram required analysis before it could be understood the method must have been terribly confusing. There may be some advantage in removing or covering up anything that is likely to distract attention ; but, on the whole, the tendency of part-time students is to concentrate on what the teacher is doing or saying, and it is in the few minutes before the lesson begins that they examine anything in the room.

If students are required to make copies of wall diagrams and if they are required to have exact knowledge of the construction of the machine or structure or plant displayed, regard must be had to the fact that details will be more easily seen by those sitting in the front row than by those sitting farther back. There are a number of diagrams in use in Technical Schools which are defective in this respect. They are not large enough to show the smaller details. In these cases the diagram should be supplemented by another one showing the details drawn to a larger scale. This may have to be done on the blackboard.

Visibility to all the students is particularly necessary if the detail is essential for the working of the machine or apparatus. A technical drawing must very often embody not merely outline and construction, but function. It must be possible to ascertain from the drawing how the apparatus or machine works. The writer has seen many drawings in which this condition was ignored. A commonly occurring example is to be found in sketches of chemical apparatus in which a tube is represented by a single line. This is a careless and slipshod practice which should be severely repressed. There are many cases in which a very simple diagrammatic arrangement is permissible—e.g. electrical circuits, but a drawing of a piece of chemical apparatus involving open channels for the flow of gases or liquids should be more explicit.

Where a large number of drawings of relatively small objects or parts of larger objects have to be

made, the simplest plan is to distribute hectographed or cyclostyled copies round the class. This condition frequently arises in Trade classes. It is also a good plan in these cases to devote a certain portion of the lesson period to this work. If the students endeavour to draw while the teacher is talking they are likely to miss what he says. If it is worth his while to say it, it is worth while for the students to listen to it.

Whenever it is possible the actual object should also be available, so that it may, if necessary, be handled and compared with the drawing. This helps the student to visualize a solid object from the flat drawing, and vice versa. Students' drawings should, if they represent mechanical devices, be made on squared paper. Not only does this save time, but it facilitates making the drawing in correct proportion. It is also an advantage to put in a few leading dimensions, and to add notes on material, construction, and mode of operation.

When the student is attending a course including definite instruction in drawing he can usually make reasonably good sketches, and there is a distinct advantage if they follow the usual system of orthographic projection. Plan, elevation, end-view, and section are rarely all required, and the student should be encouraged to use the smallest number of views from which all the dimensions can be obtained.

In spite of the fact that all students have received some instruction in drawing before they come to the Technical School, it is very often found that they can

make only very poor drawings of apparatus. A few hints will often remove the defects.

Many years ago, when students were much less satisfactorily prepared than they are to-day, the writer used to give his students in Chemistry the following suggestions :—

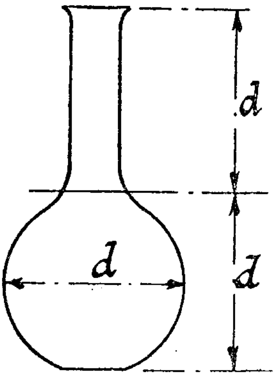

FIG. 5.

(1) While flasks from different makers differ in shape, a flask of suitable shape has the dimensions shown in Fig. 5 all the same. Avoid making the neck too narrow.

(2) To draw the top of a thistle funnel which is not too restricted at the mouth, first draw in pencil an oval as in Fig. 6 (*a*). Then put in the lip and tube as in Fig. 6 (*b*), and rub out the lines at *x* and *y*.

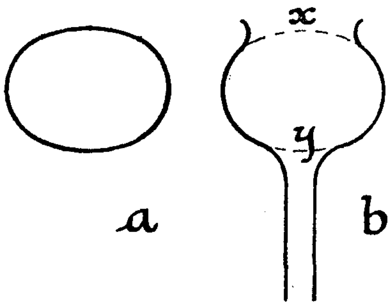

FIG. 6.

(3) To obtain a smooth, pleasing curve in the delivery tube from a flask to a pneumatic trough, draw the flask first, then the tube, and then the trough. If the bottom of the flask and the

trough are not then at the same level, draw a block of wood under one of them, as shown in Fig. 7.

The teacher of drawing may smile contemptuously at this plan ; but it was effective.

Lantern slides are usually welcomed by students as a change from the other forms of class activity, but beyond this there is nothing to be said for their use

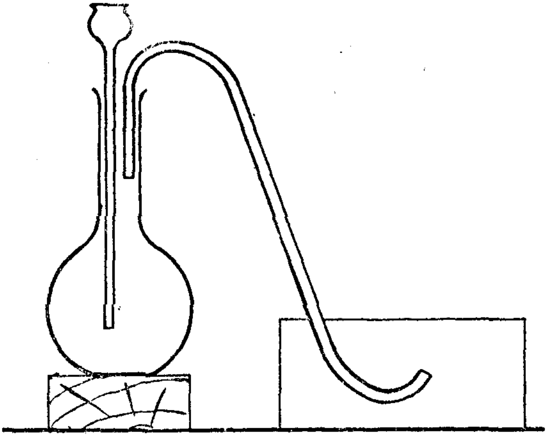

FIG. 7.

in the case of simple diagrams. They are, however, very desirable for showing the general arrangement of industrial plant. These are often taken from books or from Technical Journals. A permanent diagram can easily be made from the lantern slide by projecting it upon a large sheet of paper and tracing it with a broad-pointed pen, such as is used for poster-writing. This may be the more necessary as the slides cannot

remain in the lantern long enough to permit the diagram to be copied.

We may close the discussion on Drawing as a form of illustration by pointing out that it is supplementary to verbal description. It is easier to fill the mind with a picture than with a number of sentences. When these sentences describe an object, such as a machine, or a structure, or a woman's dress, the mind has to make a mental picture with each phrase or sentence. With a drawing the student can pass from the whole to a part, from one part to another, and back again to the whole. And a verbal description accompanied by a drawing make a clearer and more permanent impression than either used separately.

Perhaps the most attractive form of illustration is the experiment—and it suffers more than any other from lack of intelligence in its use. We shall endeavour, therefore, to analyse the purposes it serves in the scheme of instruction.

The primary purpose is to help the student to understand something which cannot so easily be understood by a verbal description or explanation, or a drawing. If the lesson is on certain phenomena of Heat or Light or Electricity a piece of apparatus is so arranged that the phenomenon can be observed as well as the conditions necessary for its production. Many experiments reproduce what goes on in the world of Nature. They are reproductions of natural phenomena on a small scale. In a lesson which involves a description of a machine, the principle upon which it

works may be demonstrated to the class by a piece of apparatus designed for the purpose.

These experiments are very desirable, but they are not always essential for understanding. Many years ago the writer was a student in a class in Sound, Light, and Heat, in which only two experiments were performed during the session. One of these was the freezing of water, by its own evaporation, in Wollaston's cryophorus. It was a cold night. The teacher and students sat round a fire in a corner of the room with the apparatus in front of them—and it didn't work. The other experiment was quite successful. The teacher sounded the middle C on a tuning fork.

There is an old story of Todhunter, the famous mathematician. He is said to have gone to Germany for a holiday, and while visiting one of the Universities he saw a piece of apparatus which he did not recognize. On making an inquiry he was told that it was an air-pump. "Really," he said, "I have lectured on the air-pump for twenty-five years, and I have never seen one before."

But learning without experiment has its limitations. It is only possible as a rule when the experiment is a replica of some phenomena or device with which the students are familiar. A considerable amount of elementary Mechanics and Physics *is* merely a systematization of everyday experience. We cannot so easily visualize a chemical reaction without experimental aid.

The second purpose of experiment is to convince

students of the truth of a law or principle. That can be done in two ways. A number of experiments can be performed by the students under Step II, the results examined, and the law or principle abstracted, or formulated. While this is the natural procedure by which most scientific knowledge is acquired, there are two dangers inherent in the plan. One is that the results may vary too widely to justify any inference being drawn from them. The other is that the conclusion may be based on an inadequate number of experiments. The teacher who uses this method would be wise to adopt the formula : " If it is true in these cases it is *probably* true in all. I can assure you that no careful experiment has ever given a result which is at variance with the principle."

This plan of making students " discover " things for themselves was some years ago carried to an extreme. The students were never deceived. They knew the teacher possessed the truth all the time. But with young students it was, and still can be, quite exciting. And it had another value. It involved both team work and competition. They were all engaged in the same quest, and no one desired that his result should detract from the credit of the joint enterprise. The main condition of success is to choose the topic for this treatment and not to ride the hobby to death.

The disadvantage of the method was its extreme slowness, and the writer has seen classes of older students thoroughly bored with it. The whole plan was too transparent. They were under no illusions.

They could not imagine themselves discovering what has required centuries of human effort to discover. They had come to the class to learn what was known and they wanted to get on with the job.

The alternative use of experiment in connection with a law or principle is that of verification. If the purpose is to obtain a physical constant it may appear to belong to Step II, but in most cases it involves an application of the law and belongs to Step IV.

The important feature to bear in mind is that an experiment is not an end in itself but a means to an end ; and it should be carefully selected in the light of the purpose which it has to serve in the whole scheme. That is particularly important in laboratory work. Much of this bears no relation to the theoretical instruction, and beginners suffer seriously in consequence.

The relation between lecture experiments and experiments by individual students has been subjected during the last forty years to the swing of the pendulum. Originally there were few laboratories and little laboratory instruction ; but the lectures were often well illustrated. Then laboratory work became a sort of fetish, and as it increased, the experimental illustration of lectures—especially in Physics and Mechanics—decreased. The pendulum is now swinging slowly back again.

The fact is that some things are learnt most easily by individual experiments, and some students learn most readily in that way. For example, the only way

of learning how to connect up electrical circuits is to connect them up. And the same statement may be made in regard to chemical analysis. If the experiments are woven into the web of method some will be done by the teacher and some by the students. It is a matter for the teacher's own judgment.

He should consider whether an experiment, well and neatly performed, with a piece of apparatus that all are able to see, is not as effective as, or more effective than, one which the students perform themselves. They are often clumsy, with hands stiff from exposure and manual labour, and they are so much concerned with the muscular control necessary for manipulation that they are unable to think what the experiment really means. If, on the other hand, the teacher performs it, they are free to concentrate their minds on the meaning and purpose of the operations, and on the interpretation of the result.

Another consideration is whether the students are likely to do any more experimental work at all in the course of their studies. There are many attending classes in Mechanics, Physics, and Chemistry, who will proceed to Trade Classes. Such laboratory training as can be given to them in a session will not have much value beyond its contribution to their understanding of the subject. For these students the time devoted to individual experiment may be more limited than is possible or desirable in the case of students who will have to continue that type of work.

There is a great danger of laboratory work being

carried out in a perfunctory manner, especially in evening classes where time is limited. Cleanlinesss and tidiness should be insisted on from the beginning. It is desirable to direct the student's attention to possible sources of error either in the apparatus or in the method. They can appreciate this even though they may not, at that stage, be able to make the connections. The experiments will usually be performed with more care, and more intelligence, under this direction. In Physics they will usually have received instruction for a year or two before they enter the Technical School, and attention may be directed to sources of error in the first year of the Senior Course.

We may reiterate finally that experiment is only one of the devices that are available to the teacher, and it should have a clear and definite purpose in the scheme. For beginners, especially, laboratory work ought not to be treated, as it so frequently is treated, as a more or less independent subject.

Models and Specimens

The purpose of models and specimens is, in the main, to supplement verbal descriptions. The appeal to the senses of sight and hearing instead of to hearing only increases the vividness of the impression. A model, moreover, is more useful than a drawing in that it represents the object, machine, or device in three dimensions. Nevertheless, the possession of a model does not reduce materially the desirability of having a drawing also. The two are more or less

complementary. Some features—e.g. a section—can be more easily shown on a drawing than in a model. Models from which parts can be removed to show the interior are usually expensive.

We may refer under this head to a form of " model " of which too little use is made. An experiment may be of a kind that cannot easily be performed on the lecture table, and yet, for which there is no time in the laboratory. It is assumed that reference to it in the theoretical lesson is inevitable, and that it will usually be illustrated by a diagram or blackboard drawing. It is suggested that a more effective illustration would be a " dummy " arrangement. The apparatus would be set up just as though the experiment was to be performed. The students would carry away with them a more vivid and permanent impression than could be obtained from a verbal description or drawing.

Again, a " dummy " arrangement of industrial plant can be made with blocks of wood fixed to a drawing board with painted or chalked arrows showing the flow of material. This kind of model would be particularly useful in certain branches of Technology.

Specimens of materials are essential if the subject of instruction is to bear the stamp of reality, and these specimens ought to be constantly available for inspection by the students. To store them away in the recesses of a cupboard and to bring them out to decorate the front edge of the lecture table once a year is not to make full use of them. It is throwing

away much of the advantage which their possession confers on the teacher and the class.

There is a certain professional body in this country which requires candidates for its examination in Chemistry to be able to recognize common substances by their appearance. There is also a certain educational institution which prepares students for this examination. But the common substances or "chemicals" are kept in a store-room under the vigilant eye of a steward who only relinquishes possession of them under instructions. The only materials with which the student can become really familiar are the reagents on the laboratory bench allotted to him. These are, for the most part, colourless liquids. To become familiar with materials a man must *live* among them.

Visits

In planning visits to Museums, Exhibitions, and Works it is necessary to remember that people only observe what they have been trained, formally or informally, to observe. There should, therefore, be some sort of preparation for the visit. The students should be informed of the general nature of the place they are to see, and should be advised as to the features to which it is desirable that they should direct their attention. The excursion is then not one of aimless wandering and casual sight-seeing.

Many works are of such a character that it is easy to draw a plan of the works, which may be quite conventional, showing the successive stages in the

treatment of the material, and with arrows indicating its passage through the works—a flow diagram. This device is appropriate to Gas Works, many Metallurgical works, and other manufacturing organizations. The student then has a framework into which he can fit the details which are brought to his notice.

We shall have occasion to refer to these devices again when dealing with specific subjects of instruction in the next chapter.

CHAPTER V

SPECIAL METHOD

We propose to consider in this chapter the application of the General Method and the Devices of Teaching to specific subjects or groups of subjects. Obviously this consideration must be limited to brief comment and suggestion. As the teacher's method is most important when dealing with young students, and with beginners, the suggestions and illustrations will, for the most part, refer to the elementary stages. Though the teacher will carry his method beyond that point, he will bear in mind that his students acquire each year habits of study for themselves, and while he will have regard to the general order of treatment and the use of various devices in appropriate circumstances, he will be careful to avoid over-elaboration. Nothing is so irritating to older students as to be treated like children.

MATHEMATICS AND MATHEMATICAL SUBJECTS

As Mathematics begins, for many evening students, in the Preliminary or Preparatory course, and as the Technical School teacher must have regard to what the students have done before they enter his class, it is necessary to say something about the work done in

Junior Institutes before dealing with that in the Technical School. The purpose in the Preparatory course is not so much to continue what the boy has learnt in the Day School, as to develop or extend those aspects of mathematics which will be most useful to him in his technical studies. It would obviously be absurd to attempt to carry on, in one lesson a week, instruction which has hitherto occupied four or five. In comparison with full-time instruction all part-time instruction has necessarily to be abridged.

In general the first year of the lower course will consist of revision of fractions, decimals, and percentages, mensuration of the commoner plane and solid figures, the first four rules in algebra, algebraic factors, and simple equations. Time is saved if fractions, decimals, and percentages are taken together. A percentage may be regarded as a vulgar fraction in which the whole is always divided into a hundred parts, and a decimal as one in which the whole is divided into ten, or a hundred, or a thousand, or some other number represented by 10^n. Ample practice should be given in the conversion from one form to another. Algebra ought to be taught from the very beginning as generalized arithmetic. Thus $\frac{3}{4} \times \frac{5}{7} = \frac{15}{28}$ and $\frac{a}{b} \times \frac{c}{d} = \frac{ac}{bd}$. Mensuration will begin with length, and, using graphic notions from the beginning, a line may represent also time or price. In fact if length is taken as the starting point all the arithmetical processes can be revised, and algebraic processes introduced, by dealing with linear quantities. Interesting problems

can be given at an early stage. The relation between distance, velocity, and time can be expressed in the formula $s = vt$, and the students introduced to the simple mathematics of motion. This can be extended when the class passes from the consideration of the lengths of straight lines to those of curves; for velocity in a circle leads to problems on the speed of pulleys and belts.

The idea of direction should always be introduced between the idea of length and the mensuration of plane figures. The area of plane figures depends upon their shape, and the shape depends upon the inclination of their sides. In dealing with the simpler properties of plane figures, such as the conditions of equality of triangles, the relation between the triangle and parallelogram, and between triangles and parallelograms on equal bases and between the same parallels, free use should be made of tracing paper. There seems to be a widespread and persistent reluctance to take advantage of this valuable aid to instruction. It is astonishing to find the number of cases in which it is not used when it ought to be.

Mensuration of the simpler plane and solid figures provides the opportunity for introducing algebraic factors. If the teacher takes these separately he will almost certainly use geometrical illustrations; and an illustration introduced *ad hoc* is never so effective as one which arises naturally. The ordinary course of teaching provides the apperception mass for this purpose.

From what has been said about groups of ideas and the desirability of connecting them up to form a coherent and well-articulated whole, it will be obvious that the instruction will be all the more effective if it has *continuity*. The course outlined consists of *facts* and *processes*. There is very little connection between the processes, and they have to be reduced to subconscious habits—that is, the student must become so accustomed to using them that they never occupy the centre of his thoughts. The facts are what he has to keep in memory. They are the data of practical problems, and the data are what he has to reason about. In the above course they have a definite logical relation to one another. The teacher will be well advised, therefore, to make the core of his teaching Length (and linear quantities), Direction, Area, Volume (and weight). Each of these forms a large section, which should be subdivided for purposes of teaching. The arithmetic and algebra will then accompany this core, and as they are always derived from, and applied to, things having length, time, price, inclination, breadth, thickness, volume, and weight, the instruction will have a concrete basis. The student will be primarily engaged in acquiring ideas of the geometrical properties of the world in which he lives, and he will acquire incidentally habits of dealing numerically and algebraically with these properties.

This is Practical Mathematics—an attitude or method rather than a subject. The student acquires a few ideas about mathematics but, what is more

important, he acquires mathematical ideas which prompt him to deal numerically with problems that lend themselves to quantitative treatment.

It is not, as a rule, desirable to extend the teaching on a geometrical basis for more than one year. The geometry becomes too difficult, or beyond the requirements of the students. But a new basis can, if desired, be found in Mechanics, Heat, or Electricity treated in a quantitative way, and according to the Four Step Method.

A second year Preparatory Course ought to include a revision and extension of the algebra of the first year course, partly for the sake of students who omit that year. It should include a revision and extension of the mensuration, not so much to the more complex figures, as by means of a more powerful instrument—trigonometry. This, to be effective, involves logarithms, and the use of logarithms is desirable at this stage as a labour-saving device.

The final aim of the second-year course should be to familiarize the students with the relation of the equation and the line, and it is suggested that this should be preceeded by ratio, proportion, and variation. Every problem in variation is concerned with the instantaneous values of the quantities. The graph shows continuous variation. Incidentally, it is better to keep statistical graphs separate from graphs of equations. Statistical graphs are merely methods of representing problems by scale drawings.

In arranging such a course it is well to teach new

processes, which do not arise out of what has just been done, as early as possible in the session. There is thus ample time for the students to become familiar with their use. The sections then become—Revision and Extension of Algebra; Logarithms; Scale Drawing Methods; Trigonometry and Mensuration; Ratio, Proportion, and Variation; and the Equation of a line. With this foundation the student can enter upon any subject in the Senior Course which requires a knowledge of elementary mathematics, and he need not be embarrassed because the teacher of mathematics in the first year of the course has not yet dealt with a part of the subject which is required in one of his other subjects.

The general scope of a suitable Preparatory Course has been given some detail because this work is often done outside the Technical School. The teachers are often uncertain as to what is required of them, while the teacher in the Technical School is frequently unaware of what has been done elsewhere. There should be much closer co-operation than is customary.

It is less easy to indicate precisely the content of Mathematics in the first year of the Senior Course. The students are often separated at this stage according to industry or occupation, and the requirements differ considerably. For engineers, emphasis is usually laid on mensuration, geometry, and trigonometry. For chemists, these parts of the subject are of less importance. But in both cases an increasing knowledge of, and dexterity in manipulating, algebraic expressions,

and equations and graphs, are of primary importance. The expansion of a binomial expression should also be introduced.

It happens too frequently that separate classes in mathematics for different grouped courses cannot be arranged, and students have to attend a class in which the instruction omits or lays little stress upon matters which are important to them. This defect can be reduced considerably if the students are separated into groups in the mathematical class, and occasional special lessons given to a group while the others are working exercises. The matter is more important than it may appear at first sight. In Engineering Courses mathematics is taught for at least three years. In other courses it may appear in the first year only of the Senior Course. If that one year of mathematics is to carry the student through three years of Chemistry or Gas Engineering or some other subject, careful selection of material is necessary. The engineer can often afford to leave a mathematical process to the second year ; the chemist cannot.

It should be noted that the chief need of the chemist for mathematics is with respect to Physics and Physical Chemistry. Purely chemical problems fall almost entirely under ratio and proportion. On the whole, a satisfactory one-year course in mathematics which will carry the student through the senior course, can be arranged. More, however, is required by those who take Physics and Physical Chemistry for the Higher Certificate. The simplest way of providing this is to

include the additional mathematics in the syllabus for Physics A_1. It will occupy five or six weeks at the beginning of the session.

Syllabuses in Practical Mathematics often contain the qualification that a rigid proof is not required. In the old days of Pure Mathematics proofs were required to be rigid. But it is certain that many students did not understand them. Young students especially will accept any proof the teacher gives them without understanding and without question. The fact is that proofs, like definitions, and general laws, convey more to trained mind than they do to the untrained. And what is required in the establishment of a science, and what is necessary to convince a beginner, may be two different things. If a student is to be trained as a mathematician—that is one task; if he has to acquire mathematical knowledge merely in order to learn some other subject—that is another task. In the latter case demonstrations are justified. If a non-rigid proof—such as the proof of the binomial theorem on the assumption that the series is convergent—is given, it should be qualified. The justification for a proof of any kind is that it is intelligible to the students, and that it gives them confidence in the equation in which the truth is expressed.

Another common recommendation is that students should be taught not to work out a solution to too many figures. But this ought to be put on a rational basis. In each year the students should become

familiar with the measuring instruments used for determining the quantities which enter into their calculations, and with the degree of accuracy of which these instruments are capable. No student should be allowed to remain under the misapprehension that the avoidance of too many figures is desirable merely to save labour.

All mathematical study involves a certain amount of drill in order to secure speed and accuracy. A very good plan is to set aside a period of twenty minutes every week for working "mechanical" exercises. It is essential for success that these should be merely "mechanical". There should be no differences of data to distract attention from the process. In this way the process is repeated a number of times and reduced to sub-conscious habit, whereas without deliberate training of that sort, a whole session may be spent without the working of the process becoming habitual.

The plan might well occupy some of the time usually devoted to miscellaneous examples. The disadvantage of these is that they *are* miscellaneous. They are not graded. They are useful as tests of progress but are not arranged on any *teaching* plan. A certain example may be a rather difficult one of its class, and the student cannot work it without aid from the teacher. The teacher helps him—and the matter is over. The student may or may not have acquired an increase of analytical power.

But suppose that particular example is one of a series,

of which the first is the simplest and each one that follows adds a fresh complication. Then the first problem is easy enough for the student to solve it without help. Having solved the first, he sees at once how to do the second; and, having done the second, the method of attack on the third is obvious to him. In that way he approaches the most difficult case, and is able to work it out without aid.

If the mere description is not convincing, consider the following examples :—

(i) A train travelling at 60 m.p.h. passes a man standing on a railway station platform in 2 seconds. What is the length of the train ?

(ii) If the train in (i) is 60 yards in length, how many seconds does it take to pass the man ?

(iii) If a train 60 yards in length travelling at 60 m.p.h. takes 10 seconds to pass a railway platform, what is the length of the platform ?

(iv) If a train 60 yards in length passes a platform 100 yards in length in 8 seconds, what is the speed of the train ?

(v) If two trains 60 yards and 80 yards in length travel respectively at 60 and 45 m.p.h., how long will they take to pass one another (*a*) when they are going in the same direction and (*b*) when they are going in opposite directions ?

(vi) Find the lengths of two trains moving at given speeds when they take specified times to pass one another, in the same and opposite directions.

The miscellaneous examples will probably contain only (iii), (iv), (v), or (vi).

The teacher who has not tried this plan will be rather astonished at the rapidity with which a student acquires skill and confidence. It is in fact a method of training him to think out a problem from first principles.

As the student proceeds through even the early stages more and more attention should be given to the precise meaning of the symbols and operations. On these matters the teacher would find it useful to read, if he has not already done so, Sir Oliver Lodge's *Easy Mathematics for the General Reader* (Macmillan) and Professor A. N. Whitehead's *Introduction to Mathematics*, in the Home University Library. Long before these books were published, the writer found Professor W. K. Clifford's *Common Sense of the Exact Sciences* (International Scientific Series) very suggestive.

It has been remarked on p. 75 that elementary Mechanics, Heat, and Electricity lend themselves to treatment as the core of a course in Mathematics. If the teacher of one of these subjects is also responsible for the instruction of the same students in Mathematics, he has an excellent opportunity, not only of saving time, but of giving reality to the Mathematics. Thus, using the Four Step Method, experimental work will yield a body of figures (Step II) from which the law may be inferred (Step III), the equation and its graph will be associated, and the constants determined. This

equation will then be applied to the solution of problems (Step IV). Even if the teaching of Mathematics is in other hands he would find it an advantage to emphasize the mathematical aspects of his subject—provided he is teaching students of a professional type in a major course. Minor or Trade course students require different treatment, and we may now devote a word or two to their needs.

The practical type of mind does not assimilate easily Mathematics *qua* Mathematics. It deals in the concrete rather than the abstract; in the particular rather than in the general. Calculations are incidental to the job. They consist almost entirely of mensuration and calculation of quantities of materials; more rarely of prices and costs. One of the most effective examples the writer has seen was a class in Metal Plate Work. Each night's work consisted of a drawing—usually a development, a calculation of the quantity of material required, and an estimate of the cost for one or a hundred, as was appropriate. It should be noted that a second night in the week was devoted to Geometry.

There are other types of student for which rather more than this is required, but the necessity for examples bearing upon the student's occupation remains. Beyond a certain stage, Mathematics will not help him. He cannot assimilate it and has no use for it if he could.

In all these non-professional courses the scope and standard, and therefore the nature, of the mathematical

teaching should be based mainly on the workshop course. That is the dominant factor, and to that Mathematics, Drawing, and Science are subsidiary.

Subjects Studied through Scale Drawing

The second group of subjects for consideration includes those which are mainly studied through scale drawing. In the major courses they are Engineering Drawing, Building Construction, Geometry of Building, Naval Architecture, and subjects of similar character. They all assume, however, that the student has already acquired some knowledge of Practical Geometry in a Junior Institute or elsewhere. It will be advisable, therefore, to consider the Preliminary or Preparatory Course first.

In the Preparatory Course " the students acquire a knowledge of the more important geometrical facts and relations ; they obtain some facility in the use of instruments, and in the commoner constructions of plane geometry ; and they learn how to represent a solid object on a flat surface. The first aim is more important in the first year, the third aim in the second year, and the second aim should be kept in view in both years ".[1]

The first year's course may deal with circles and tangents ; properties of parallel straight lines ; triangles ; rectangles ; and simple projection of solids. The instruction should include the geometrical properties as well as with the methods of construction, and these should be demonstrated by drawing and

[1] Prospectus of the Union of Lancashire Institutes.

measurement, the use of tracing paper, and other experimental methods.

The second year's course may comprise triangles and polygons; similar figures; loci and simple linkages; more difficult problems on circles and tangents; and orthographic projection of the chief solid figures.

In both years students are usually expected to show proficiency in sketching—geometrical models, common objects, tools, and simple machine or constructional details being indicated. This work is often taught in special periods, and has no relation to the instruction in which instruments are used. It is almost, in practice, a separate subject. But as much of it as possible ought to be associated with the geometrical exercises. Even the sketching of plane geometrical figures provides excellent practice in proportion, and in each year all the exercises in solid geometry will lend themselves to practice in sketching. It would be advisable for the teacher to consider first how much practice in this kind of drawing he can provide in connection with the geometry, and he will then be able to make a minimum list of additional examples. Even a screw-driver and an oil-can are capable of being incorporated in the systematic and orderly treatment of the subject.

Sketching for technical students is not to be regarded as a "look and see" process. The student is drawing something which, as a rule, he has seen and handled. He has some idea of the construction, and of the purpose, of the object. And that construction and that

purpose should be explicit in his drawing. If, in the course of his occupation, he has to make a sketch, that is what will be expected from him.

It would appear, at first sight, that the formal steps are inapplicable to a subject like Practical Geometry. But this is not quite true. The student is expected to become familiar with the chief geometrical facts and relations. In other words, he is expected to become familiar with general truths. These can be inferred from the construction and measurement, or comparison with tracing paper, of plane figures, each student making the figures of different dimensions. The construction and measurements or comparisons form Step II of the formal plan. The generalizations can then be applied to simple problems, though the rigid proof of a " rider " cannot be expected. This is particularly appropriate to the first year's work.

In other cases the drawings may lend themselves to a summary. In all cases the problems should be grouped, and the groups divided as sharply as the " sections " in a subject studied through the medium of language.

So far, drawing has been regarded mainly as a " knowledge " subject. But it is also essentially an art, in which it is necessary for the students to acquire skill. That is, they must learn to draw neatly, accurately, and quickly. The teacher should insist from the very beginning on the conditions necessary for neatness and accuracy—pencils of suitable grade, properly sharpened, and care in marking off dimensions.

Inaccuracy may be due to laziness ; or to the student's lack of control over the muscles employed in drawing ; or occasionally to defective sight. A student who had just obtained a pair of spectacles told the writer that he could never understand before why, when he drew a line with a straight edge, it did not appear straight !

It is most desirable that, in all cases of apparently slipshod work, the teacher should endeavour to ascertain the cause. It is brutal to badger a student whose poor work is the result of a physical defect. A student who lacks refinement of muscular control should be encouraged to make his drawings on a larger scale and with a somewhat bolder line. The lazy student should be warned that he will suffer the consequences at the examination.

Speed in the manipulation of Tee square, set squares, and instruments, can be acquired by mechanical exercises, as in the case of Mathematics. A short period may be devoted to the drawing of a *particular kind of figure*. The exercises should be simple so that the *operations* are repeated a number of times. In some classes these speed exercises are required by only a few boys. These may be given while students who work quickly are engaged on an extra example. In view of the great differences which are found in the rate of working, it is desirable that the syllabus should contain the examples to be drawn by all the class, together with a selection of additional or more difficult examples to be drawn by the quick workers. If that is not done there may be, during the session, a good

deal of unfinished work, and considerable waste of time.

In Engineering Drawing there is such a profusion of examples, suitable even for beginners, that it is not easy to make a selection. This must, however, be the first step, and as far as possible two conditions should be observed. The first is that they should be graded in order of difficulty, and the second is that the order should be intelligible. It will be convenient to arrange the subjects in sections, and to make one or two sheets of drawings in each section. The machine parts on these sheets should be regarded as main types, and sketches of different types, with notes on material or construction should accompany the sheets. The student will thus acquire an organized body of knowledge with a central core running through it.

It is not desirable that these sheets of drawings should be mere copies of what is set before the student. Sketches of details (from models of actual examples) may be assembled to form a whole. Other views than those given may be required. A very valuable exercise, which may be used more freely in the second year, is to require a student to draw a particular detail from a drawing of a more complicated whole. That trains him in the analysis of a drawing, a process which must always be employed in any attempt to "read" it. Furthermore, most, if not all, the drawings should be dimensioned. The teacher would be wise, in this matter, to keep in view the recommendations of the

British Standards Institution on Standard Drawing Office Practice.

It is generally desirable to keep to some sort of standard in selecting the parts to be drawn. If a student draws a crank, cross-head, and piston, these should be for the same engine, or for engines of similar type and size. To draw a cross-head for a 10 h.p. engine and the big end of a connecting rod for a 5,000 h.p. engine is apt to upset a student's sense of proportion. That would be unfortunate in regard to his future career, because an almost, if not quite, subconscious sense of fitness is one of the factors of design. The others are dimensions and strength, and facility of construction in the shops.

Because design is so largely dependent upon facility of construction, and because engineering apprenticeship is served in many cases in a specialized department, it is desirable that some instruction should be given in the processes involved, particularly those which are carried out in the Foundry and Forge. There are classes in which one or two demonstrations are regularly given on moulding early in the session.

Though the title of the subject is Engineering Drawing, the real purpose of the instruction is Engineering Construction, and the older name of Machine Construction and Drawing was both more explicit and more correct.

In sketching it used to be considered sufficient to make orthographic projections on squared paper. But in recent years there has been a tendency to encourage

pictorial views based on isometric projection. In the writer's view oblique projection is simpler and easier, serves the same purpose, and might well be equally acceptable.

The remarks on neatness and accuracy on pp. 85–6 in connection with geometry apply equally to Engineering Drawing. But the differences in speed of working may be very much greater in the latter subject if some of the students are in a drawing office. The best method of dealing with this difference is to provide alternative examples differing in difficulty. That is far more satisfactory than to allow the class to straggle out in a line of increasing length during the session. There can be no satisfactory "class teaching" of construction if the students are not "standardized" more or less at the beginning and the end of each section.

Building Construction differs from Engineering Construction in several important respects. In the latter the material in which the work is to be executed is invariably a metal; in the former brick, stone, concrete, timber, and steel are used. The "trades" which enter into building operations are much more distinct than those usually recognized in engineering. Moreover, during the past thirty or forty years the nature of building has changed considerably. A great deal of the joinery—doors, window-frames, etc.—is now purchased ready-made. Concrete and steel frames are replacing brickwork, and masonry for the main structure of large buildings. But for students

in the first and second year of the Senior Course it is usual to confine attention to houses of the normal construction and moderate size.

The first step is to divide the year's work into sections, and the second to select the types of the structural details to be drawn with some care in each section. These will be supplemented by sketches of variations from the type selected, geometrical constructions, and notes on material and construction.

As much of the work as possible should be done from the student's own measurements and sketches. Most of the drawings at first will be "assemblies", but some practice should be given in abstracting a detail from a more complicated drawing. Much of what has been said in connection with Practical Drawing and Engineering Drawing apply also to Building Construction. In all subjects there should be frequent reviews and summaries to fix what has been learnt in the students' minds. The internal "edifice" is as important as the external.

Subjects Taught through Experiment

The third group of subjects are taught very largely through experiments, performed by the teacher in the lecture room or by the students in the laboratory. In the main they are Mechanics and Physics in the Preliminary, or Preparatory, Course, and Physics, Chemistry, and Applied Mechanics in the Senior Course.

The Preliminary or Preparatory Course usually

includes the simpler portions of Statics and Hydrostatics and Heat, with, in some cases, the elements of Electricity and Magnetism or Chemistry. In Statics the experiments are both easy and obvious, and often time is spent on them which might more profitably be devoted to calculations. Statics is based rather on explanation and definition than upon experiment, and the value of experiment lies rather in the emphasis which it gives to the law or principle which it illustrates.

Sir Oliver Lodge, in the Preface to his admirable little book on Mechanics (W. & R. Chambers) remarks that: "The subject is treated as an introduction to Physics, and its laws are deduced from the first principles of familiar experience rather than from special experiment. Experiments in Mechanics have a subordinate though most useful purpose in illustrating and emphasizing the facts, but the author has no faith in making the establishment of principles depend on special experiments."

This does not mean, of course, that no experiments need be performed, either by the teacher or the students. It merely emphasizes the fact that the main purposes of experiment are illustration and verification. Like several other subjects in the elementary stage, Mechanics is largely common sense applied to everyday experience—an analysis, systematization, and extension of what everybody knows but is not conscious of knowing. Definitions and laws have to be driven home and fixed by plenty of numerical examples.

The subject should first be arranged in a convenient number of sections. The first of these will deal with force. When, as is customary in part-time classes, statics precedes dynamics, there is a difficulty in defining force, and it is better not to attempt it. Everyone is familiar with force through the exercise of his own muscles, and it is better to collect the students' experience as to the various effects of force with which they are familiar. They can proceed to consider how forces can be measured by the strain they produce in a rigid body. They can then pass on to the specification of a force and its representation by a straight line.

The most controversial point at this stage arises in connection with the parallelogram and triangle of forces. Some teachers believe in approaching the triangle of forces directly ; others prefer to approach it through the parallelogram. The writer has a strong preference for the latter, and older, plan, especially for young beginners.

But that preference does not extend to the customary type of apparatus used to illustrate the law. The students should first understand that a force may be applied to a body under three conditions—free to move in any direction, fixed at one point but free to turn, and rigid. It will be well to deal with the third case first, because strain provides a means of comparing forces. Then the first case can be considered. The apparatus preferred by the writer is an irregular shaped piece of thin wood with a number of holes

bored through it. On the under surface are three hemispherically headed upholsterer's nails. This is placed on a sheet of paper on a drawing-board which has 2 in. wire nails driven in near the edges. For measuring forces calibrated spiral springs are used. The procedure is as follows :—

1. A spring is hooked to one edge of the thin board. What happens ? The board moves. In what direction ? In the direction of the force.

2. A second spring is hooked on and both are hooked to nails near the edge of the drawing board. The body (thin board) is now at rest under the two forces, and is said to be in *equilibrium*. Note the extensions of the springs and mark the direction of the two forces with four pins. Remove the body and springs, draw lines through the pin-pricks, and state the results ; the two forces are equal, opposite, and in the same straight line.

3. Proceed to examine the effect of three forces. Note that any one is the equilibrant of the other two. Select one as the equilibrant, note the forces, and mark the directions as before. Produce the equilibrant beyond the point of intersection and convert the "pull" in to a "push". Show that this is the diagonal of a parallelogram of which the other two forces form the sides.

4. The same apparatus may be used for teaching the principles of moments.

This plan is much quicker than the ordinary vertical arrangement, and avoids the error due to the weight of

an irregular body in that form of apparatus. If no irregular body is used then the fact that the forces meet at a point is rendered obvious by a knot in the cords, or is implied by attaching them to a ring. The students learn very quickly from a demonstration with this apparatus, and have more time left for working out exercises—graphically in the first year, and by the aid of very simple trigonometry in the second year.

Whether students perform the experiment or not does not seem to the writer to matter a great deal. The apparatus is so simple that every student can understand how it is used, and the main purpose of the teaching is to present the principle so simply and so clearly that they can understand and remember it. To secure its retention in their memory they should work a number of examples. An experiment *of this sort* by individual pupils followed by, say, three examples, is far less effective than an experiment by the teacher followed by ten or a dozen exercises. If the student is to make reasonable progress these fundamental calculations should be reduced as quickly as possible to sub-conscious habit.

A more useful piece of laboratory work than mere repetition of the experiments described would be an application to a simple appliance, such as a jib crane. Once the principle has been learnt it should be associated with some practical exercise that gives it a meaning and a purpose. Experiments performed by the teacher have often to be of a kind which renders them inappropriate for repetition by the students.

For presenting a principle the apparatus should be as simple as the teacher can devise. A generally sound criterion for suitable laboratory apparatus in Mechanics is that it should bear the impress of reality.

We may illustrate this point from Hydrostatics. The displacement of a liquid by a solid immersed wholly or partially in it may be demonstrated by the teacher by any of the ordinary methods. But young students should have the opportunity of lowering a painted brick, suspended from a spring balance, into a bucket of water. Nothing so impresses upon them the upward thrust of the water as the effect upon their own muscles. Moreover, the use of such a common thing as a brick lifts science out of the laboratory and brings it into the students' own everyday world.

Relative density and flotation is another part of the subject in which a lot of calculation is better than too much experiment. The teacher will find it an advantage to "group" the arithmetical exercises—to set a number of examples on the same subject using different units—the British and the C.G.S. Miscellaneous examples can be used at the end of a section as a test.

There are certain pitfalls for the inexperienced. The usual methods of showing that air has weight involves the idea that it is elastic. It is better to take the properties of matter for granted for a time. They are only intelligible on the basis of a good deal of observation. They are, in effect, generalizations, and though it is desirable to reach general conclusions as early as possible, there is nothing to be gained by

introducing them before the students are able to appreciate them.

Heat is another subject which illustrates the importance of modifying method to subject. No student comes to the class unacquainted with thermal phenomena. Everybody knows something about hot bodies and cold bodies, about solids, liquids, and gases, and about changes of state. The knowledge is, no doubt, vague and confused, but it is there, and it is the teacher's business to clarify, correct, and organize that knowledge in the boy's mind. He can do that right from the beginning. In fact it would be desirable to complete that first, for another reason.

It is impossible to deal with the measurement of temperature without assuming a knowledge of the expansion of solids and liquids. Similarly it is impossible to deal precisely with the expansion of solids, liquids, and gases without assuming a knowledge of temperature. Recognizing these facts, the writer, many years ago, made his first lesson a survey of all the obvious phenomena of heat—temperature, expansion, change of state, conduction, convection, and radiation. It was illustrated by a large number of experiments and was intended to bring up into the mind of the students common everyday knowledge. After that it was immaterial whether one proceeded to thermometry or expansion. And from the very beginning it was possible to consider losses by conduction, convection, and radiation. The conditions of successful experiment cannot be understood when

these three phenomena come, as they often do come, only at the end of the course.

Generally, in the first year a quantitative treatment is unnecessary. It will be sufficient if the students become familiar with the effects of heat and the experimental way of studying them. But there should be numerous illustrations from everyday phenomena. The future occupation of many at this stage is uncertain, and there are often no clearly defined occupational interests. The students should learn that though science may have to be studied with all sorts of queer apparatus in a laboratory, it is not a remote and abstruse subject. They should learn that it is intimately connected with their daily experiences. No other subject lends itself so readily to this purpose.

In the second year advantage should be taken of the opportunity to treat superficial and cubical expansion algebraically. It is an excellent method of introducing the student to the idea of quantities so small that they can be neglected. The higher mathematical standard of the students in this year will enable them to understand the gas laws and the absolute scale of temperature on the gas thermometer. In fact the whole treatment at this stage should be quantitative. The student is already familiar with the phenomena ; his ideas need to be made more precise.

Some difficulty is occasionally experienced in calculations of specific heat. They need not arise if plenty of practice is given in calculating heat lost and heat gained before any attempt is made to equate the

two. In these calculations both English and Metric units, and Fahrenheit and Centigrade scales should be used.

In the laboratory the attention of the students should be drawn—usually by discussion—to possible sources of error, even though they may not be able to avoid them or to make the necessary corrections. This encourages a more intelligent appreciation of the experiment, and the students acquire more than a knowledge of the mere routine of performance.

It will be convenient to carry the consideration of Physics now into the Senior Course. It appears under that name only in courses in Chemistry and allied subjects. In Engineering it is concealed under the title Engineering Science. We shall deal for the moment with Physics and defer consideration of Engineering Science.

There has been a tendency for Physics in the first year of the Senior Course to be little more than a repetition of the Preparatory course. There has also been another tendency to require students to attend a Matriculation class. Physics and Mathematics in Technical Colleges are almost the only subjects which are not the central subjects in an industrial course. Mathematics is required in all of them and the syllabuses are drawn up with special reference to the requirements of students. Physics occurs in few, and in some Colleges the energies of the Physics Department have been concentrated on preparation for Matriculation and Intermediate Science. Neither of these

syllabuses is exactly suitable for a National Certificate Course in Chemistry. There are, from this point of view, important omissions and undesirable inclusions.

The teacher is faced, in this first year, with the task of providing instruction which will be really beneficial to the student of Chemistry and which will avoid mere repetition. What a student of Chemistry and allied subjects needs at this stage are some of the broader conceptions of Physics, as well as a more detailed knowledge of physical measurements. In a considerable group of Technical Colleges the syllabus begins with elementary dynamics—velocity, acceleration, momentum, and kinetic energy, and then proceeds to a study of the subject in the light of the Kinetic Theory of Matter. This not only renders phenomena more intelligible, but creates a more coherent picture of the physical world.

For example, the existence of a mechanical equivalent of heat is deduced from the Kinetic Theory. Again, the most important physical properties of liquids are due to cohesion (surface tension and capillarity) or to a conflict between cohesion and independent motion of the molecules (vapour pressure). The student is encouraged to seek explanations of external phenomena in the constitution of gases, liquids, and solids. His previous knowledge of external phenomena is extended very little, but his understanding is vastly increased.[1]

[1] See the author's *Solid, Liquid, and Gas*, The English Universities Press.

In laboratory work it is inevitable that there should be some repetition ; but the experiments should be carried out with apparatus capable of greater accuracy, and with increasing regard to possible sources of error.

The only really new ground is in dynamics, and this is very largely a matter of explanation and definition. Each new idea should be fixed by working a number of simple examples. Experiments are important to illustrate the laws—not to establish them. A great deal too much use is made of Fletcher's trolley, and

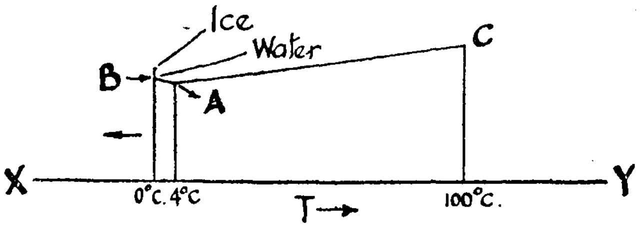

FIG. 8.

too little of apparatus like Hick's Ballistic Pendulum, or rows of balls in a groove. Apparatus of this sort was much more frequently used thirty or forty years ago than it is to-day.

The teacher's chief difficulty in Heat at this stage is to revise and extend, without exactly repeating, the previous year's work. This can often be done by discussing a phenomenon with the class. For example, the following have been found useful in summarizing and extending what the students are supposed to have learnt.

1. Let temperature be measured along the line XY from left to right in Fig. 8. Draw at 4° a perpendicular line representing, say, the volume of 1 lb. of water at that temperature. Draw at 0° C. and 100° C. perpendicular lines representing the volume of the same weight of water at those temperatures.

We can imagine a pound of water sliding up and

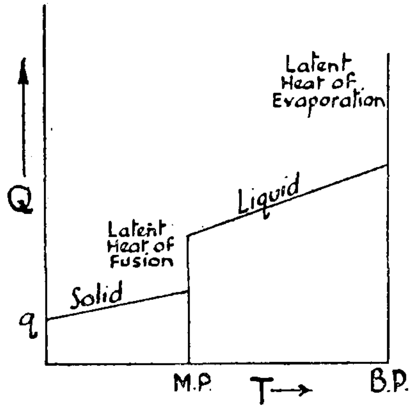

FIG. 9.

down the temperature line, and filling the space between that line and BAC. Suppose water at 0° C. is frozen. The volume is increased by 9 per cent. Next suppose that pressure is put upon the ice so that the volume is reduced below B. What happens? The ice melts.

What must be done to solidify again without releasing the pressure? It must be cooled

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Hence a substance which expands on solidifying has its freezing point lowered by pressure.

The argument may then be applied to the case of a body which contracts on solidifying, and to the effect of pressure on the boiling point.

2. Draw a diagram, Fig. 9, showing the relation between quantity of heat and temperature in the case of a particular substance in a solid, liquid, and gaseous condition.

Let unit weight of the solid containing q units of heat be taken. Then for each degree rise in temperature a quantity of heat equal to the specific heat is required. This holds good until the melting point is reached, when the temperature remains constant until the latent heat of fusion has been absorbed. By continuing the supply of heat to the liquid the curve rises until the boiling point is attained. The temperature again remains constant until the latent heat of evaporation has been supplied.

This diagram involves the definition of specific and latent heat, and emphasizes the fact that during change of state the temperature remains constant.

There is a very simple and interesting extension of this diagram. The attention of the class may be drawn to the fact that a gas may be heated either at constant volume or constant pressure, and that the specific heat at constant pressure, C_p, must be greater than that at constant volume, C_v, by the work done in forcing back the atmosphere. These

two specific heats may be used to extend the curve in a forked branch as in Fig. 10, the less inclined one being based on C_v and the more steeply inclined one on C_p. If now a line be drawn through o parallel to the line of temperature, any perpendicular XYZ to that line will be divided by the C_p and C_v lines in such a way that $\frac{XZ}{YZ} = \gamma =$ the ratio of the specific heats.

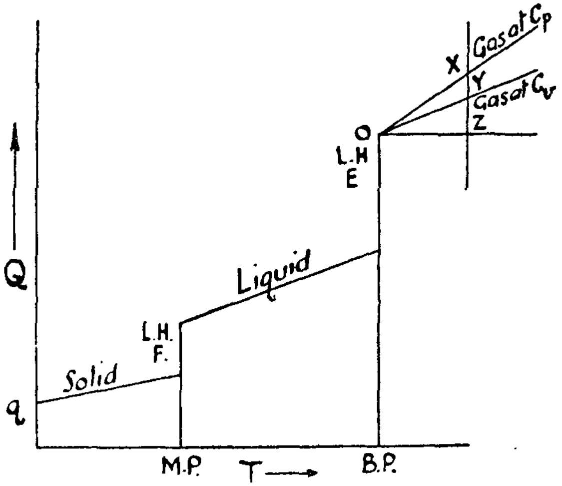


FIG. 10.

As an additional refinement in laboratory work we select the determination of specific heat by the method of mixtures. The chief difficulty here is in measuring the final temperature. The most satisfactory method is to take temperatures every half-minute, draw a cooling curve with temperature as ordinates and times as

abscissæ, and then produce the curve backwards until it cuts the temperature line at the time of mixing. This gives a very close approximation to a temperature which, owing to cooling, cannot be measured directly. Moreover, the ingenuity of the method renders it especially attractive to students.

The first-year course in Physics usually includes an introduction to Light. There is no time for more than a very simple treatment of Geometrical Optics. The aim is to render intelligible the construction of the simpler optical instruments. Physical optics is of much more importance to the student of Chemistry and that should be deferred until the second year. It is an advantage then to deal with Radiation as a whole and not merely with Light.

A little Electricity is often included in the Preliminary or Preparatory Course, because a few electrical devices are employed in elementary Chemistry. It is continued in the second year course, when the teacher should keep three aims in view. The instruction should enable the student to use the laboratory supply of electrical energy intelligently ; to understand the use of electricity in industrial processes ; and to understand the electrolytic theory of solution. As we have remarked before, all part-time instruction has to be abridged. In some cases this is accomplished without serious loss by fusion, as in the case of the treatment of Radiation. What has to be done in the senior course is to provide *useful* instruction to students who may receive no more in this subject.

However elementary the treatment of Electricity may be, it should be quantitative as far as possible. This is particularly true of Ohm's Law, in which the students require plenty of arithmetical practice. A second condition is that there should be plenty of laboratory work in which the students have to make up their own circuits. These are not easily learnt through oral explanation, or from a book. Purely qualitative experiments have little value in the laboratory. They are better treated as the more spectacular incidents in lecture-demonstrations.

Emphasis is laid on qualitative treatment as a result of the writer's experience many years ago, when he taught a class working for the Science and Art Department's examination. The syllabus made no reference to calculations and the examination questions were consistently descriptive. These conditions were observed in the teaching in the first session ; but not in the second. It was found that numerical exercises were necessary in order to give precision and permanence to the ideas.

There was another subject in the Science and Art Department's Directory which was practically impossible to teach satisfactorily. It was called, if the writer's memory serves him, General Elementary Science, and it was apparently intended to be " science without tears "—or arithmetic. That created one difficulty. Ideas lacked precision. Another difficulty arose from the very wide field covered—all branches of Physics and Chemistry. So little time was available

for each that the students never acquired more than fragmentary knowledge of any portion. There was not enough to make an apperception mass in any part of the syllabus. The old Section I Physiography suffered from a similar defect. There were too many topics.

It is a conclusion of experience that no more than three sets of topics, such as Mechanics, Hydrostatics, Heat, Light, Sound, Electricity, Magnetism, should be included in the syllabus of a session's work. In each set of topics there must be a sufficient number of ideas to form an organized body of knowledge. The mind cannot work upon fragments.

In considering the work in Mechanics and Physics done in Engineering classes, it is necessary to note that while in some Colleges the Mechanical and Electrical Engineers are provided for separately, in others there is a common first year course. The latter is of considerable advantage to the smaller schools in which the numbers will not always permit of separate classes. The joint syllabus in use in a large group of schools affords an interesting example of what we have called "fusion". The headings of the syllabus are Force, Work, and Friction, Machines, Electro-technics, Energy, and Power.[1] Incidentally, there are not here five sets of topics, because the first three are essentially Mechanics. But under Work and Friction occur "Mean Effective Pressure"; work done "per stroke and per horse power". This used to appear under the

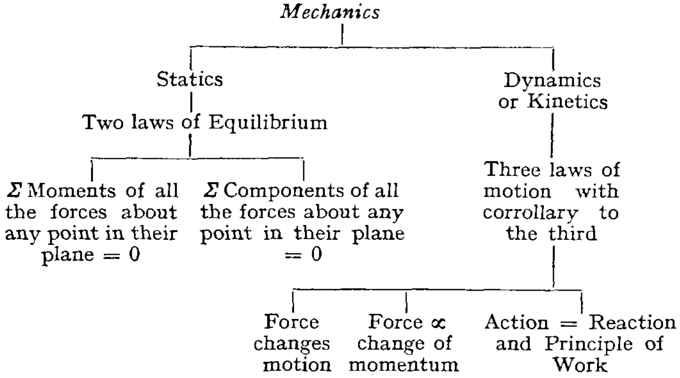
[1] Prospectus of the Union of Lancashire and Cheshire Institutes.

heading of Heat Engines. Again under Energy and Power there is the mechanical equivalent of heat, latent heat, total heat of dry steam, and use of steam tables, as well as the electrical and mechanical units of energy and power.

Where the Mechanical and Electrical Engineers are treated separately the work for Mechanical Engineers is divided into Applied Mechanics and those aspects of Heat which are important in the study of Heat Engines.

Before teaching on either of these syllabuses is attempted, teaching sections should be formed. It must be noted that most of the principles have been dealt with in an elementary way at the preparatory stage, and these principles with a few new ones are being applied to practical problems. Some care and judgment is necessary to ascertain whether the students really know what they purport to know. It should also be noted that a good deal of the work set out in the syllabus, especially that on machines, is essentially laboratory work and calculation.

In regard to the sections it may be noted that topics which, at the preparatory stage, are treated separately, may often in the senior course be combined. Thus while inclined and parallel forces have previously been accorded separate treatment, they may now be grouped under the general conception of equilibrium. And that leads to another point of interest. There is some danger, when teaching an applied science, of ignoring general concepts. For example, the general scope of Mechanics may be illustrated by a diagram.



It is very desirable that a generalization of this sort should be introduced even in the first year. Dynamics is not as a rule taught until the second year, so consideration of Newton's laws would have to be deferred. But a summary of this sort is of immense value in crystallizing a student's mind-content. It emphasizes also essentials which he is apt to miss in the " confusion of ideas " in a session's work.

There is one aspect in which the sectional method of treatment facilitates the organization of laboratory work. The apparatus cannot in many cases be duplicated. But if the aim (Preparation) of the section is clearly indicated, and if that aim covers a wide enough field, the order in which experiments are undertaken does not matter. The students change over from one set of apparatus to another, until the Presentation is complete for all. Thus levers, beams, centre of gravity, equilibrium of a body on an inclined plane, forces in a jib crane, or simple pin-jointed frames,

may fall in one section. Similarly most, if not all, machines fall into another. The plan can only be followed completely when the teacher has full use of both lecture room and laboratory. But it is one to be adopted as far as conditions will permit. The plan by which elementary students are engaged in laboratory exercises which have no relation to contemporary theoretical instruction is indefensible. It can only occur if the teacher is ignorant of, or indifferent to, the purpose which laboratory work serves in the scheme of instruction.

Building Science includes Statics treated rather more fully than in an engineering course, and a good deal on the special properties of building materials. It lends itself to the treatment which has been outlined. The subject can be dealt with in sections, and the results can be formulated or summarized. The laboratory work would also benefit by grouping the experiments in a section, in the way suggested for Engineering Science.

The only other important subject taught largely through experiment is Chemistry. The teacher is at once faced with a difficulty here in that students who have entered from a Preparatory Course will rarely have learnt any Chemistry, while those who enter from a Secondary School may have done a good deal. Teaching the class in two or three groups, which is possible in Mathematics or Drawing, is not possible in Chemistry. On the other hand no group of students in the class must feel that the teaching is over their

heads, or that it is being directed mainly to the needs of another group. Something may be done to alleviate the situation by skilful questioning and class discussion. Occasional questions directed to those who *know* may be used to convey information to those *who do not* know, instead of the teacher providing it. The students who *know* will probably not realize exactly the teacher's purpose, but they will feel at any rate that they are not being neglected.

There is a well-established tradition that a beginning should be made with air and water, the two commonest materials of the students' environment, and the media in which most chemical changes take place. The instruction will necessarily consist of short topics, but the teacher should keep in mind the larger section. That is to say, he should frequently pass in review what has been done, building up first small units or subsections, and then the larger units or sections.

Until a fair amount of material has been accumulated it is not wise to expect students to understand. All chemical changes are detected by physical changes. The chemical change is not seen. And it takes a little time for the mind of a beginner to see beyond the outward and visible signs, the inner meaning of the experiment. The teacher will keep himself informed of the students' understanding by questions and class discussion, but ability to reason independently cannot be expected until a sufficient number of facts have been assimilated.

In view of the strain upon the memory created by

many unfamiliar substances with strange names, frequent summaries are of first-rate importance. They are essential, too, in order to enable generalizations to be reached as quickly as possible. Emphasis should be laid on general reactions. Thus hydrochloric acid is produced by the action of sulphuric acid upon any chloride, not merely on common salt. By the end of the first year course the student should be able to suggest methods for the detection of oxygen, hydrogen, carbon, and other elements in a substance of unknown composition.

It is often advisable to teach too much, rather than too little. For instance, in connection with the preparation of nitric oxide the students should know that results of the action of nitric acid on metals vary according to the nature of the metal, the concentration of the acid, and the duration of the reaction. But they should realize further that hydrogen is probably first liberated, and that this gives different products according to the rate at which it is produced and the concentration of the acid upon which it acts.

The student will have to learn a good deal at first which will require qualification or correction afterwards. As a salt is produced by the neutralization of an acid by a base, he regards a salt as a neutral body—except in the case of a substance like $KHSO_4$. But that will not matter for a year. The subsequent modification of something which has been *understood* is more satisfactory than confusion at the beginning.

As he proceeds he is gradually acquiring the knowledge which makes the qualification or correction necessary to him. It is much to be desired that at some later period—say in the third year of the senior course. there should be a brief, but systematic treatment of the elementary theory of salts.

In addition to the commoner non-metallic elements and their compounds, the student acquires incidentally in the first year course a considerable acquaintance with other elements or their compounds—e.g. sodium, potassium, calcium, copper, iron, phosphorus, and silicon. It is a good plan to round off the year's work with an elementary study of these elements. This is an excellent way of revising what has been done and provides a broader foundation for the second year course.

In regard to this second year course, three recommendations may be made. The first is that the elements should be grouped in accordance with the periodic classification. There is no need to elaborate the reasons for, or justification of, the table. It may be regarded as a convenient way of displaying in close association elements which have similar chemical properties. A satisfactory explanation of the periodic law belongs to the third year.

The second recommendation is that industrial processes should be taken separately, and not, as is commonly done, in association with the element concerned. Furthermore, these processes should be grouped according to the principle upon which they are based—e.g. furnace reactions involving oxidation

or reduction, vat reactions in which replacement or neutralization is involved, electric furnace processes, and electrolytic processes. The reason for this recommendation is that it involves classification and comparison of industrial processes, and thus collects and treats in a systematic way topics which are scattered as isolated fragments amongst the systematic survey of the elements and their compounds. In this way it emphasizes the *principles* of industrial operations, and enables the picture of the elements and their compounds to be more clearly defined.

Psychologically, the common plan leads to mixed apperception masses. A mass which should be primarily concerned with a group of elements and their similarities and differences, is complicated and confused by alien ideas of the large scale production of one or two materials.

The third recommendation is that a little time should be given to fundamentals—equivalent and atomic and molecular weight, Arogadro's law, and so on. It is astonishing how soon these fundamentals are forgotten, and how frequently students are unable to explain clearly why the formulae for oxygen, hydrogen, and water are written O_2, H_2, H_2O respectively. These are not difficult, but they require clear thinking. Though they are dealt with in the first year it is probable that many students only apprehend the arguments vaguely; and unless they are required to go through the reasoning from time to time they lose their familiarity with it.

A curious mistake occurred in some papers which passed through the writer's hands on one occasion. A number of students confused thermal with electrolytic dissociation. That could only be the result of careless teaching. The fact that it has occurred is useful to know. Skill in teaching often consists in knowing what mistakes students are liable to make—and in seeing that they do not make them.

The selection of laboratory exercises demands especial care. In the first year they ought to be closely associated with the theoretical instruction. They should not, too frequently, be repetitions of those performed by the teacher on the lecture table. The experimental work involved in learning the subject should be divided between the teacher and the students. If the students realize that, the realization gives them a more serious view of their own work: that does not consist merely of playing about with glass tubes and making stinks.

The relationship between the lecture and laboratory work in the second year is rather different. The students are required to prepare substances by typical reactions, to learn some qualitative analysis, and to have some practice in volumetric estimation. The qualitative analysis is the main difficulty. A good deal of routine is involved, and it cannot be kept in close touch with the theoretical teaching—at first, at any rate. On the other hand occasional short talks about the separations emphasize and reinforce much of the instruction in the lecture room.

One sometimes finds a definite lecture period given

in the second year on the theory of analysis. There is no time for this in a properly arranged part-time course, and it is too early in the course to introduce it. All that is required can be given in a few ten-minute talks in the laboratory.

A good deal of time might be saved if the three types of exercise are carried out on the same material. A preparation may be tested, qualitatively for impurities, and then one of the constituents estimated volumetrically. Any plan that varies the routine of qualitative analysis is good, and any plan that encourages elasticity of experimental method is good. The opportunity to achieve these ends occurs with increasing frequency as the session advances, and the teacher should map out the laboratory exercises with his theoretical syllabus in front of him.

Sufficient use is not always made of volumetric work as illustrative of the theoretical instruction. In the first year it may reinforce the students' knowledge of the relations between acids, bases, and salts. In the second year it may be employed to illustrate the electrolytic theory of solution. Both of these uses give the experiments a wider implication than they would possess as mere laboratory exercises.

There is one other matter—which may be expressed as an instruction rather than a recommendation. That is the insistence on the most scrupulous cleanliness and tidiness. Test tubes, beakers, and flasks must be kept clean ; anything spilt on the bench must be immediately wiped up. The students must

learn that accuracy and slipshod methods are incompatible.

Subjects Mainly Descriptive

The fifth group of subjects are those which are mainly descriptive in character. They may conveniently be discussed in three sections—Technology, Industrial Crafts, and Domestic Crafts—with a note on the Artistic element in Craftwork.

(*a*) *Technology*. By the word Technology we mean the rules and principles which govern the operations of a manufacturing industry. The students require instruction in certain subjects of Pure and Applied Science, such as Mathematics, Physics, Chemistry, Applied Mechanics, Heat Engines, Engineering Drawing, Electrical Engineering, or Electro-technics, as well as a description of the processes and plant employed. Under the grouped course system the instruction in Pure and Applied Science is given in separate classes, and though the teacher of Technology will take advantage of this he will often find it necessary to extend the students' knowledge as well as to describe its special application to the industry which forms the subject of his own instruction.

The statement that a Technology is a description of a manufacturing industry now requires qualification. The manufacture contemplated is that of a material rather than an object, though the material may appear in various forms or in a variety of objects. The main point is that the material passes through a series of processes which may be mechanical, or physical, or

chemical, sometimes being split up into products of different texture or composition, and yielding various by-products in the course of these changes.

This distinction between the manufacture of materials, and objects such as machines or houses or furniture, will be clearer if a few industries with a "Technology" are enumerated: Gas manufacture, Coke manufacture, Paper manufacture, all the Textile industries—cotton, wool, silk, artificial silk, Leather, Rubber, Celluloid, and other "Plastic" materials, Flour Milling, Iron and Steel Manufacture, and Metallurgical industries generally.[1]

The reader will observe that these fall into two groups—those in which the raw material undergoes chemical change, and those in which it undergoes a change of form. The former are, strictly, chemical industries, the latter mechanical. The distinction is in a few cases not very clear. Certain raw materials certainly undergo chemical change but so little is known about the change that it is not easy to say definitely that the industry is a chemical one. The mere employment of an engineer or a chemist does not settle the matter. Some chemical changes occur in most mechanical industries; machinery is employed in most chemical industries; the real point at issue is whether the chemical or the mechanical processes are dominant. The undoubtedly mechanical industries in the foregoing list are Textile group, Flour Milling, Paper manufacture, Rubber manufacture, and Plastics

[1] Such a subject as Boot and Shoe Manufacture lends itself, in the first year, to the treatment outlined.

hover between the two divisions because of the empirical character of the chemical processes involved.

This analysis is of some importance because the teacher of a Technology should first arrange his subject in the order of the dominant processes. He should begin with the raw material and should follow it through the various changes, indicating, but reserving for fuller treatment, the by-products which are either marketable, usable, or difficult of disposal. All auxiliary machinery or appliances should also be reserved. An excellent plan is to provide every student on the first evening with a simple flow-diagram, showing the main stages in the passage of the material through the works.

Having gone through the whole scheme in that way the teacher may come back to the beginning and describe in greater detail modifications of plant, together with auxiliary machinery and appliances; or he can defer the modifications of plant for a third survey. Thus in Gas Manufacture the teacher will first deal with the carbonization of a typical gas-coal in horizontal retorts, the effect of temperature on the products, cooling, purification, and storage. He can then in a second survey describe vertical or inclined retorts, coal and coke handling machinery, mechanical chargers and dischargers, exhausters, governors, and meters. Lastly, in a third survey he can deal with water-gas plant. In each case the subject will be treated in sections, with careful summaries in Step III. Where there is a variety of plant or appliance—e.g. hydraulic mains, charging or discharging machines, governors or meters,

it is advisable to describe a familiar one first and then unfamiliar ones by comparison. As the lectures cover two hours, and a considerable amount of sketching has to be done, it is a good plan to set aside twenty to forty minutes for this purpose.

It will be observed that the method is generally adaptable to both chemical and mechanical industries. The first survey provides the student with the simplest picture of the nature and purpose, and the order, of the essential processes. The second survey enables him to fill in this picture with the less essential details. In this way a syllabus which reads like a series of paragraphs on more or less detached subjects, is converted into a coherent body of knowledge in the mind of the student.

Gas Supply, consisting of a number of detached items, would seem, at first sight, rather difficult to treat according to these principles. But the difficulty is only apparent. The first survey should deal with the means of conveying gas from the works to the consumer's appliances, and should include the devices for regulating and measuring the flow. This should be followed by combustion and burners, and then by outdoor lighting, indoor lighting, cooking, and heating appliances. The order in which the last four are taken does not matter very much

If the industry is a mechanical one it is usually important to consider with some care the precise effect on the material produced by each machine. It is for that reason that well-equipped laboratories are required

for Textile Technology. The mere handling of the machine is a secondary matter. It can be learnt more quickly in the mill. The change in the material as it passes through each machine can, as a rule, only be learnt properly under an instructor.[1] We may repeat that people only observe what they have learnt to observe.

In the case of industries in which the machinery is too large or too expensive to be installed in a Technical College, there should be occasional visits to works. The recommendation that the class should be "prepared" for the visit may again be emphasized. The visit should be arranged for a particular purpose, and that purpose should be clear to the students before they go. With a class of advanced students the "preparation" may often take the form of a short introductory lecture on arrival at the works by a member of the works staff.

In many manufacturing industries there is need for a type of instruction which is not as frequently provided as it should be. That is the training of foremen. It is usually quite different from the training provided for students of professional type. Some observations were made on this kind of instruction for men engaged in the Engineering and Constructive Trades on page 82. There, the materials and processes of the workshop were emphasized as the centre round which the instruction in Mathematics, Mechanics, and Drawing

[1] See p. 13 of *Memorandum on the Teaching of Cotton Spinning and Cotton Manufacture in Evening Technical Schools*, H.M. Stationery Office.

was planned. But in manufacturing industries, which are discussed in the preceding paragraphs, the foreman may be, and often is, engaged in a very specialized job. Even if he is in a chemical works he may need little or no chemistry. He is not responsible for the reaction. But he should know something about the physical and mechanical principles upon which the operation of the plant or machinery, of which he is in charge, is based.

These men are, as a rule, of mature age. Though they are beginners they cannot be treated as young students. Though they are often highly intelligent, they cannot be treated as advanced students. They require a special technique of teaching.

So far as the physical, mechanical, or any chemical phenomena are concerned, it is better, as a rule, not to attempt a systematic and continuous course. Groups of ideas bearing on their work will provide them with what they require. Thus, appropriate groups are Density and Specific gravity, the Chemistry of air and water together with acids, bases, and salts, the Chemistry of air and combustion, the Measurement of Temperature, and so on. This instruction can be given on one evening in the week, and more specific instruction on their work on a second evening; or it can be introduced into the more technical instruction as and when required.

The writer makes no apology for recommending a popular, or semi-popular, treatment. The popular prejudice against popular knowledge is based on a

strange misconception. Most of the knowledge we possess is popular knowledge and we find it extremely useful. It provides us with points of contact with our environment which otherwise would not exist, and it adds enormously to the variety and interest of life.

(*b*) *Industrial Crafts.* Before considering Industrial Crafts some explanation of the term is desirable. A craft involves, essentially, *doing*, rather than *knowing*, though, as was pointed out in the first chapter, the craftsman should *know* something about his materials, and he should *know* why he adopts a particular procedure. This knowing, however, is subordinate to the doing.

The word Industrial has been used to exclude the Domestic Crafts, which are considered in the next section, and Artistic Crafts, in which the element of decoration is of primary importance. What the writer has in mind are fitting, turning, or tool making, moulding, pattern making, founding, and forge work, in an Engineering works ; metal plate work ; carpentry and joinery, brickwork, masonry, plumbing, gas fitting, bread making and confectionery, and a host of other trades.

It will be obvious that for their proper understanding several of these occupations call for a considerable knowledge of science ; but, as a rule, most of the students are not of the type that responds readily to instruction of an academic character. Drawing is essential and the students can do this. They can do it with the greater ease the more directly it bears upon

the things they make. And the same statement will hold in regard to calculations.

So far as practical work is concerned the first necessity is that the exercises should be carefully graded. The students will probably vary considerably in manual skill, and the minimum work for the session ought to be within the capacity of *all* the students. At any rate, it should be capable of completion by the majority. But it is a good plan to arrange for a series of more complicated examples than the type for students who have already had considerable practical experience. This grading may be based on tools or materials.

As an illustration of grading, reference may be made to Gas Fitting. This subject is often attended by quite young boys whose practical experience of tools and materials is limited to fetching and carrying for the fitter. They are sometimes set to work at the beginning of the session on lead pipe, which is a more difficult material to handle than, say, $\frac{1}{2}$ in. brass tube. Any degree of accuracy or neatness with lead pipe at first is out of the question. But brass tubing is fairly well adapted to their strength and skill.

Generally speaking the skill which the student acquires in a Technical College lies in the handling of tools and materials and the order of procedure, and not in the degree of accuracy which is attained only with the experience the student will have in his daily work. With that experience he will also acquire speed, and speed cannot be acquired in a limited period of

workshop instruction. The student learns how a job should be done, and what mistakes to avoid. The job should be done to the best of the student's ability. Skill, in an economic sense—a sense which involves speed, is acquired by many repetitions of a job well done, and not by any number of repetitions of a job badly done.

In some cases emphasis can be laid on the importance of doing a job well by using one exercise as the basis of the next. If the first is not done sufficiently well, it cannot be incorporated in the larger one.

It is obvious that the objects made should be the students' own work. The teacher should watch how each student sets about his work, and should immediately correct faults in the use of tools, or procedure. He should explain, wherever possible, the nature of the mistake, and the reasons for correction. He may frequently *show* the student how to proceed, but in doing this he should complete as little of the work as possible.

All workshop instruction should be accompanied by theoretical instruction on tools, materials, and processes. The essential features and proper use of the tools should be described, the origin and nature of the materials, their merits and defects, should be dealt with, and explanations given of the nature and purposes of the processes wherever this is appropriate.

For some trades, Drawing need hardly be a separate subject. Young students, at any rate, may be expected to have attended a Preliminary Course in a Junior

Institute, and to have acquired as much knowledge of geometry as is necessary. The drawing they need to practise subsequently is sketching, and in that matter the writer has a strong predilection for squared paper. It saves time and facilitates drawing in good proportion.

In subjects like Carpentry and Joinery, Brickwork, Masonry, and Metal Plate work, further instruction in Descriptive Geometry is essential. The syllabus should be arranged, however, to have a very direct bearing upon the theoretical instruction in the trade subject and upon the practical exercises. Subject to that condition the remarks which have been made on Drawing on previous pages are applicable here. The remarks on calculations, page 82, also apply.

The teaching of Science—Physics, Mechanics, Chemistry, to craft students is a more difficult matter. There are really three grades of students in Technical Colleges—Major Course or professional, Minor Course, and Craft Course students. Some of the Minor course students are very little inferior to some of those in certain Major courses, and some of the Craft students approximate to the Minor course type. The main difference is that in the latter the workshop instruction determines the nature, scope, and standard of instruction in other subjects.

The writer leans to the view that in *bona fide* craft courses (sometimes called artisan courses) the instruction in science might very well follow the lines suggested for foremen on page 120. There will be exceptions among the students, but provision can be

made for them. For example, classes in Gas Fitting, in which the instruction is supposed to be within the capacity of any Gas Fitting apprentice, are attended in some places by secondary school boys who are capable of taking a much more scientific course. The best plan is to allow such students to attend other classes—Mathematics, Physics, Chemistry, Engineering Science, Engineering Drawing, Building Construction. They can obtain credit for successes in these subjects on subsequent transfer to a Minor or Major Course in Gas Supply. But there is no justification for forcing all the students into a course from which many will be unable to profit.

To sum up, in most Trade classes the Science may very well be taught in sections—perhaps three or four a year, and each section may consist of a different subject. The sections must not be too small or, as has been pointed out, they will not contain enough organized material to be understood or retained.

(*c*) *Domestic Crafts*. The Domestic Crafts to be considered are Cookery, Laundry, Needlework (including Dressmaking and Millinery), and Upholstery and Soft Furnishings. Of these the first two have a definite scientific basis, though the science is not easy. Perhaps for that reason it is usually omitted, and the subjects treated as domestic arts. The others involve in the main purely manual operations combined with the element of taste and cost, though judgment is required in making a garment to fit a particular figure.

If, in Cookery, the manual operations are ignored

for a moment, the knowledge required has reference to the nature of the materials and the reasons for the processes. But dietetics and cost are in many classes of considerable importance. In other words the housewife ought not merely to understand cooking, but she should also know how to lay out a given sum of money in such a way as to combine the maximum of nourishment, palatability, and economy.

It may be said at once that any attempt to deal with the physics, chemistry, and physiology of food and dietetics on a scientific basis is out of the question. Food is almost invariably in the colloidal condition and the physics of solids, liquids, and gases is inadequate to explain its properties. The materials of the daily menu have extremely complex chemical structures, and an elementary knowledge of chemistry is quite inadequate to explain them. The fluids of the body involved in metabolism, or the changes which food undergoes after being taken, are characterized by a definite *pH* value, or hydrogen-ion content, which again hardly falls within the range of elementary science. So the teacher must perforce content herself with a more or less popular description of the nature of the materials.

A girl or woman who learns cookery should at least be familiar with the carbohydrate, protein, and fat constituents of food, and she ought to know the commoner groups of materials in which each of these is predominant. The properties of individual members of each group are not without importance. One has

only to consider albumen for a moment to realize that. It would perhaps be correct to say that most confectionery consists of an albuminous framework supporting a mixture of carbohydrate and flavouring.

But the chemistry and physics or, indeed, the art of cookery, are outside the range of this book, and the foregoing observations are to be taken as a plea for something more in the instruction than a mere dictation of recipes. What the teacher should endeavour to secure is some sort of grouping of principles or processes.

This, however, requires a good deal of thought. Very often demonstrations and practical work are taken in alternate weeks, and two or three dishes are prepared on each evening. These should, as far as possible, provide for gradation of the exercises. Thus meat may be boiled, stewed, baked, or fried, vegetables may be boiled or steamed, and sweets may be boiled, steamed, or baked. In the earlier stages of instruction the *processes* are probably of more importance than the *mixtures* and *menus*, and the more elaborate puddings or cakes should be reserved. The teacher has to consider the order of these operations in respect to the "meal" which is being prepared. It is undesirable, for example, to combine in one meal a stew with suet dumplings and a suet pudding. A light meat course should be followed by a heavy sweet, and vice versa. The writer knew a man who had to carve daily for a considerable family, and he always inquired, before carving, what pudding was to follow,

so that he could serve the portions of meat accordingly. But his wife regarded the nature of the pudding as a secret, not to be revealed until it was produced. And as she did not always adopt the rule given above, the family were liable to be over-fed or under-fed.

Recipes should be elastic. The students should be learning not merely to cook a *dish* but to cook *dishes*. Instead of a fixed recipe the ingredients may be expressed as proportional parts of one of them. The unit for cakes and puddings may be ½ lb. or 1 lb. of flour. To this may be added one-third to one-half the weight of fat, and one-quarter to one-third the weight of fruit, with two teaspoonfuls of baking powder to the lb. of flour. This mixture, with sugar and flavouring, may be baked as a cake or steamed as a pudding. The flour may be partly replaced by bread-crumbs, which will give a lighter pudding. The proportional recipe provides for variety in quantity and quality, and is, in effect, a generalization which covers a considerable number of particular cases. It can be applied, in particular, to sauces, cereal puddings, pastry, suet puddings, and cake mixtures, and gives more coherent ideas of these constituents of a meal.

In no other subject is it so important that the teacher should be able to visualize the home circumstances of the students. Many of them may live almost " from hand to mouth ". In poor districts the simplest and cheapest dish should be taken as the basis. Thus a suet dumpling for three or five persons can be made as follows, and will cost so much. It is more palatable

if raisins are added. But raisins are rather expensive. Would chopped figs be more cheaper ? How, generally, can the most economical dish be made more palatable at a low cost.

In junior classes the girls may also be receiving instruction in arithmetic, and a good many of the exercises may well bear upon the cost of meals and the economics of housekeeping.

In arranging the practical work the provision of equipment must be taken into account. It is highly improbable that the oven accommodation will be sufficient to enable all students to bake a dish on the same evening. But if the syllabus is arranged in sections, and the sections cover two or three or more weeks, the students can change over from one process to another, and be all together again, with no process or dish missed, at the end of the section.

Great importance should be attached to the way in which meals are served up. Cleanliness, tidiness, and taste not only render the food more appetizing to those who consume it, but they create in the one who prepares it a pride in her work. And this pride will be reflected in the greater interest, and greater care, which she displays in subsequent exercises. There is an artistic element in cookery quite apart from icing and other forms of decoration.

Regard might well be had to the changing conditions of life. There was at one time a prejudice amongst teachers of cookery against packet foods. That would be ridiculous to-day. In all large towns there are now

shops which supply cooked foods, and though these are not economical, their success is an indication that they serve a need. A small family of two or three could never enjoy cold beef or pork cut from a substantial joint if they relied entirely on home-cooked food. The success of these places is not due to laziness on the part of the housewife, so much as to the opportunity they afford of a more varied menu. Here, again, students can be taught that cooked meat carried home in a piece of grease-proof paper should not be dumped on a dish anyhow, but that it can be made much more attractive by the way it is served.

Another aspect of changed conditions to remember is that "season" in regard to most foods has no meaning to-day. Salads can be obtained all the year round. Meat and vegetables can be purchased in bottles, jars, or tins. Oceanic transport and cold storage enable food to be brought from distant lands where the seasons are the very opposite of our own.

The fact that practically all girls learn cookery in elementary schools renders it possible for the teacher in part-time classes to devote more attention to the nature of materials, the reasons for the processes, and the dietetic value and cost of the dishes. The actual dishes cooked are not the end of the teaching. They are incidental to the larger purpose of maintaining men and women, boys and girls, in health and vigour, whatever the income of the family may be.

Laundry work is another subject which has a definitely scientific basis. But this basis hardly comes within the range of elementary science. There are three groups of materials—the fibres of fabrics, the dirt and stain which has to be removed, and the cleansing agent. Probably the simplest method of approach is through the various cleansing agents. They can be studied in relation both to fibre and fabric and foreign material which is to be removed, and this will lead to the principles which underlie the washing process. There is obviously opportunity for a good deal of demonstration, in which pieces of fabric, suitably soiled or stained, are treated with soap, solvents, or bleaching agents. And there is obviously opportunity also for classifying the cleansing materials, as well as the properties of the fibres of which the fabrics are composed.

The instruction should also include some reference to the dry cleaning, especially, of the heavier materials. This process has been very much extended in recent years. Originally it depended upon the capacity of French Chalk, or other fine powder to "adsorb" particles of dirt, or grease. The powder was rubbed into the material and, after a time, was brushed off. In this most of the loose dirt and grease was removed. The next development was to agitate the fabrics with Benzine, which dissolved greasy matter and, incidentally, removed a great deal of the dirt. To-day certain halogen derivatives of the hydrocarbons have largely if not entirely replaced Benzine. They have

the advantage of being non-inflammable, and can, therefore, be used under conditions in which the use of Benzine would be dangerous.

The practical work ought to follow as closely as possible the theoretical instruction, and some exercises might well be included to emphasize the effect of using an unsuitable cleansing material or method on a particular fabric.

In Needlecraft classes much of the work tends to be individual, because all girls have received some instruction and have acquired some skill in the subject before they join the class. But though each one is, of necessity, making a single article or garment at a particular time, the aim of the instruction is to enable them to make not *an article or garment, but articles or garments.* A student may occupy the session in making *one* dress, nevertheless she is learning to make *dresses.* That is the first condition. And it follows that in addition to individual oversight and guidance there must be demonstrations on the principles and methods involved.

As needlecraft is a practical art, and as practical arts are founded on imitation, it is obvious that there must be in every case a model. The model may be a fashion-plate in a woman's paper; an article or a garment seen in a shop window—or on another woman; or a bought pattern. This model or pattern has to be modified to suit the person for whom the article or garment is intended, and for this drafting is necessary. The purpose of drafting is the intelligent

use of the model or bought pattern, and to provide for individual adaptation.

Thus, in dressmaking there should be frequent demonstrations by the teacher on fitting and other sections of the work, such as building up or constructing collars and sleeves. And there should also be revision of various processes, including fitting, by class-teaching, in which the students will take an active part. Individual supervision is required in regard to the stitchery, and especially in regard to the selection of the model or pattern, the variations to be adopted, and the material to be used. But unless sufficient time is given to demonstrations and class teaching each student learns to make a dress and not dresses. The main purpose of the demonstration is to convert singular into plural.

Upholstery and Soft Furnishings is another subject in which the work is largely individual. It is also, owing to the attitude of the Trade, limited to renovation. But here again, demonstrations on the main operations are essential if the students are to carry away with them anything more than the article or articles upon which they have spent most of their time.

(*d*) *The Artistic Element in Craft Work.* In certain Industrial Crafts and most Domestic Crafts there are decorative as well as utilitarian factors which have to be taken into consideration in the teaching. It is usually recommended that a collection of good examples should be available for examination by the students. If these are available they should certainly be used for

demonstration by the teacher. People only observe what they have learnt (or been taught) to observe, and the particular merits of a pattern or design should be pointed out to them. It would perhaps be well to have a few poor designs for comparison. Moreover, in the matter of dress, the teacher should bear in mind that she, herself, is serving as a model to her students. She may not be conscious of it, nor may they. The situation is a delicate one. Hardly any two people see the same thing—colour, or pattern, or material—in the same way. What each one sees, or apprehends, is a fusion of what is presented to the senses with what is already in the mind. And the mind is liable to be full of predilections and prejudices arising from temperament, and from experience or environment, before entering the Technical School. Appreciation of art is largely subjective, and there are no clear-cut standards of artistic value except among artistically trained people. Even they have been known to disagree.

A reasonable standard of taste in choice of material, colour, and design is perhaps as much as the teacher can hope to achieve. To secure this there is no better way than to compare good with bad, and as far as possible, to give reasons. What the student requires is power of discrimination, and that can best be obtained by the comparisons and contrasts which have been suggested. The teacher should remember in regard to colour that bad taste may be due to defective colour-sense. A person with this physiological defect, which is by no means uncommon, cannot, and should not, be held guilty of artistic depravity.

CHAPTER VI

PERSONAL RELATIONS

We propose to discuss in this chapter various factors which, apart from knowledge of the subject, contribute to successful teaching. It is a composite problem depending not only on personality, but also on the organization of the work in classroom, laboratory, or workshop; and this, in turn, depends upon the subject taught. A number of comments and suggestions on this aspect of teaching have been made in Chapters III, IV, and V, but they have been more or less incidental. We shall repeat many of these in order to bring together into one picture the factors involved.

The most important of these is the personality of the teacher. That is very difficult to define, not merely because it is a complex quality, but also because it may vary within wide limits. It comprises appearance, voice, speech, manner, and any other feature towards which the student or students will react favourably. A personality that is attractive to one class may be unattractive to another. The writer has seen classes in which the teacher carried the students with him by his vigour and vehemence. He has seen students attentive and industrious under a teacher whose characteristics were quietness and patience.

Personality again is a gift. A man has brought it into the world with him, and has modified or developed it before he begins to teach. Within limits he can modify it still further if he can control his behaviour, both in class teaching and in his relations with individual students.

In class-teaching he commands the respect and attention of his students if he displays a lively interest in his subject—we use the word "interest" in its popular sense here. Enthusiasm is contagious, though some students appear to be immune. But if enthusiasm is to be effective it must not be overdone. It should be reserved for matters which are really exciting, and should not be displayed indiscriminately. The students do not want to be kept continually in a state of emotion.

It is well to repeat what was said on pp. 35–7 about lucidity—loudness of voice, clearness of enunciation, speaking in phrases, orderly sequence of ideas. If the teacher is in any doubt about these matters he should practise in private speaking clearly, deliberately, and naturally. He should always be on the look out for happy illustrations. He should draw freely on incident and episode which have a direct bearing on the subject, and if these are personal experiences so much the better.

He should ascertain early in the session the previous education and the occupation of his students, and should associate his teaching wherever possible with their daily experiences. He should always face the class when talking, and he should not talk when he is

drawing or writing on the blackboard. Not only does this render his voice indistinct, but it is necessary for him to watch the faces of his students in order to note the effect of his teaching. Observation of the students is facilitated if they are in a small group. A small class should not be allowed to spread themselves over a large room. There is nearly always one in the class whose countenance is like a barometer: when it indicates "Fair" the teacher may be reasonably sure that what he is saying is being understood by all.

Students should be encouraged to ask questions. They will not as a rule interrupt unnecessarily. Older students in particular are anxious not to let anything pass that they don't understand. The teacher, especially if he is immersed in his exposition, may resent the interruption, and he may put off the answer temporarily. But if the question is a *bona fide* one it should be dealt with sooner or later. It provides the teacher with an opportunity of looking into the student's mind, and seeing the subject from the student's point of view. The question is as valuable to the teacher as the answer is to the student. If, however, the answer would involve a digression, and would therefore interfere unduly with the orderly development of the subject, the teacher should say so. But he should say it kindly, not as though he resented the question, but as though he regretted his inability, at the moment, to give a reply.

There are, of course, students who will ask questions out of sheer devilry, but they are fortunately rare. The

offender is usually a youth of 18 or 20 who has obtained a reputation among his shopmates as a wag, and who seems to feel that it is incumbent upon him to maintain the same reputation in the classroom. The writer had to deal with a young man of that type once. There are only two alternatives—Behave or quit.

There is very little difficulty in maintaining discipline in part-time classes. The students are anxious to learn and often incur considerable inconvenience and make considerable sacrifices to attend. Trouble is more likely to arise among students who are compelled by their employers to attend. It usually takes the form of deliberate shirking—inattention in class and laziness or carelessness in the workshop or laboratory. It is aggravated because the teacher hesitates to complain lest the boy should lose his job.

The method of dealing with these cases will vary with the circumstances. But two good rules are " Give every one plenty to do " and " Get to know every student personally ". We might add to the first rule " Provide variety in the lesson ". By that is meant avoid talking for too long a period, and utilize some of the other devices which were discussed in Chapter IV.

One cause of restiveness among students who attend under compulsion is too strict a discipline. There is nothing a youth who has started to earn a living resents so much as being treated as a schoolboy. The writer remembers a strike many years ago among youths of this type. They marched out of one evening school, through the town to another evening school which they

succeeded in emptying also. They were preceded by a banner consisting of a sheet of iron on which was chalked "Down with Evening Schools". The next morning they sent a deputation to the manager of the works and presented him with a written statement of their grievances. Among these were: day school subjects taught over again; the same books used; discipline unnecessarily strict. They complained that the work was uninteresting, that it was of little value to them, and that they attended under repeated threats that they would lose their jobs if they did not behave.

The only case of lack of discipline among older students that the writer can call to mind was of a different character. A class of girls of 18 or 20 were giving a young and very shy teacher of bookkeeping a rather bad time. The rule in such cases is to find the ringleader and deal with him or her individually; and it is a matter for the Principal of the school rather than the class teacher.

Mischief is likely to arise when the room is darkened for the use of the lantern or for experiments in optics. The writer used always to have a lighted Bunsen burner close at hand. He had then only to cover the air-holes with his thumb and finger in order to produce a luminous flame. An electric lamp with the switch close at hand will serve the same purpose. But the Bunsen burner had the advantage of silence, and the production of only just sufficient light to see what each student was doing. Several pieces of tomfoolery were nipped in the bud in this way. In one case, in a class

of students of both sexes, from 16 to 25 years of age, there was a sound of kissing, and the light revealed a young man caressing the back of his hand. As a rule students will indulge in mischief only if they feel safe ; but they will not indulge in it if they feel that they may be caught. It is often better to prevent a recurrence, than to make a song about what *has* occurred. The student who was discovered kissing the back of his hand looked ridiculous, and no doubt felt ridiculous. And his reputation among the other students for being smart suffered accordingly.

Whether the discipline be good or bad, it is most desirable that the teacher should endeavour to establish contact with every student. Many will answer questions readily in class ; others are too self-conscious to do so. Every opportunity should be taken—in the workshop, or laboratory, or when the others are drawing or working exercises—to talk to these. It will sometimes be found that a student is unwilling to talk about the subject. This may be due to shyness or it may have a deeper cause. He is not sure of his knowledge, and he has a horror of being told that he is wrong—or even of his ignorance being discovered. When the teacher approaches him, he is filled with dread at what he fears will be an inquisition, with possibly a reprimand, or a snub, or, at any rate, the teacher's obvious disappointment at the end of it.

But it is highly probable that such a student will answer a question about his daily work. His mind is full of that, and it is not something with which, he

imagines, the teacher *qua* teacher, is concerned. Moreover, the question is unexpected, and he has no defence prepared against it. Having once broken the ice, it will be easier on that, or a subsequent occasion, to discuss the subject with him. He really welcomes help, and appreciates interest, but for temperamental reasons he is unable to accept it in the first instance.

In his relations with individual students the teacher will become familiar with a number of mental types; and as he acquires an understanding of these and develops special methods of dealing with them, he will add greatly to the value of his instruction. The type which answers questions frequently and always wrongly has been mentioned on page 51. Another very difficult type is that super-sensitive mentality which resents correction of an error. It is not unlike that mentioned on p. 141, but is more usually found among adults. The teacher points out an error, and the student at once enters on an explanation of why the procedure was followed. The correction is, as it were, brushed aside, and the student concentrates his mind on defence. Fortunately the type is not prevalent, but when it is met with the teacher should listen patiently to the defence. When that is over he should endeavour to draw the student's mind back to the problem or exercise and go through it carefully from the beginning. He will probably hear the explanation all over again, and will have to put the correct view a second time. We hesitate to say whether a third attempt should be made. There are a few people in the world who would

rather do a thing in their own way, wrongly, than in anyone else's way, rightly.

The personal contact with individual students has an important bearing upon homework. The relation of homework to the general plan of instruction has been discussed on page 46. It has been indicated that the students should realize that the work at home is an essential part of the instruction. The exercises should be collected from each student, and if anyone has not brought his he should be asked for an explanation either at the moment, or privately at the end of the lesson, or in the laboratory or workshop. The too prevalent method of saying at the end of a lesson, " Leave your homework on the end of the table as you go out," indicates a merely casual interest on the teacher's part. If he treats homework seriously, the students will treat it seriously.

It seems hardly necessary to say that the amount of homework demanded in any one class should be fixed with due regard to the other classes they are attending. Where there are three subjects in a course there ought not to be written homework in more than two of them per week. A *rota* should be devised to secure this. Many years ago the writer discovered that students attending a course of three nights a week in a particular school were holding their homework up, and handing it in fortnightly. They had found that having worked, say, half a dozen examples in Practical Mathematics or Applied Mechanics, it was easier to do another half-dozen examples in the same subject

than to switch their minds over to another subject. The flow of thought seems to have inertia, and to resist an alteration of direction. As a consequence of this experience a *rota* system of homework was introduced into many schools, but is not often met with to-day.

Whether dealing with individual or class the most dangerous weapon in the hands of the teacher is sarcasm or cheap wit. No one cares to be made to look like a fool, and it is unfair for the teacher to make use of his opportunity. This is not meant, however, to condemn the good-humoured sarcasm that some men know so well how to use. A student will easily distinguish between unfeeling sarcasm and kindly humour.

It is often desirable to try humorous persuasion before issuing an order. Boys come to a drawing class with soft pencils. The teacher reminds them that on a certain day of the year every boy must show a sprig of oak or be nettled. He proposes to adopt a similar plan if they come the following week unsuitably equipped for their work. Or again, each boy should have a strip of emery cloth to put a fine edge on his pencil. The teacher suggests a " draw " to decide who shall buy a sheet for the use of the class.

While relations should be friendly and sympathetic, the degree of familiarity in which the teacher should indulge must vary with the circumstances. There is an old saying that " Familiarity breeds contempt " and another that " No man is a hero to his valet ",

and the teacher should be careful to permit no familiarity that would destroy his authority. For if he loses his authority he loses control, not only over the external behaviour of his students, but over their minds. If they are to follow his descriptions, explanations, and arguments, he must retain this at all costs.

In regard to drawing classes attention has already been drawn, on pp. 85–6, to the importance of ascertaining whether poor work is due to carelessness or to a physical disability. This applies to sketching as well as to work with instruments. A few minutes' conversation and a simple test or two will reveal the nature of the defect, which may be one of sight or muscular control.

Provided proper use is made of the different devices of teaching, the students can be kept fully occupied in class. There is usually little difficulty in the workshop, because an object or model will often occupy several evenings. In the laboratory—more especially in the physical laboratory—there is liable to be a good deal of waste of time. This is partly due to the fact that many exercises are simple and do not occupy the whole of the period. The teacher should bear this in mind when planning the session's work. He should not be content with merely drawing up a list of experiments; he should consider also the time that each will require and the time available. He should prepare a list of extra experiments or calculations in order to utilize the time to the fullest advantage.

A more difficult problem arises when students have to work in pairs in the laboratory. The teacher has not always a free hand in the matter. Two friends may wish to work together, and they should be allowed to do so unless there are good reasons for not permitting it. Such reasons would be that both were lazy, or mischievous, or otherwise unreliable. It is often recommended that a weak student should work with a strong one. That is a good plan if the teacher can be sure that the strong one does not do all the work. On the other hand, if two weak ones work together *one* of them at least will probably profit by the arrangement. Only a provisional grouping can be made at the beginning of the session, and if the teacher finds that any pair is not working satisfactorily he should change the grouping. In making a fresh arrangement he will be guided by the defects he has observed. But he would be well advised to press for the purchase of, or make, duplicate apparatus, so as to obviate the necessity of joint laboratory work except in those experiments which require two, say, as observer and recorder.

It is sometimes found that students, especially in practical classes, object to writing, and because they have not acquired the art of expressing themselves on paper the teacher dictates or supplies cyclostyled or hectographed notes. Under certain circumstances both of these may be justified. But as far as possible students should be required to describe what they know or what they do in their own words. The advantages of this should be explained to them. If the teacher is

in doubt he may be reminded of the line from Martin Tupper :—

> " To read, write ; to remember, write ; to know thine own mind, write."

And with those pregnant words this book may well come to an end.

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